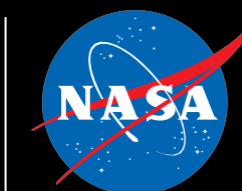
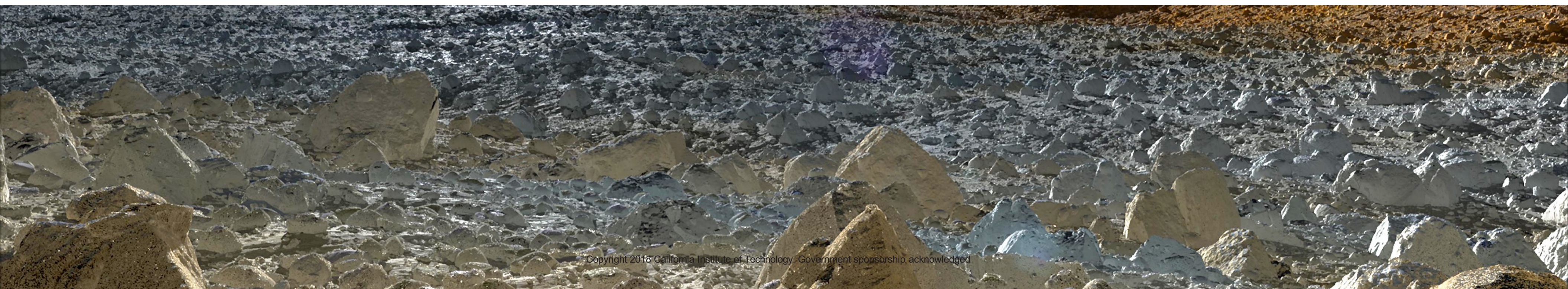


National Aeronautics and  
Space Administration

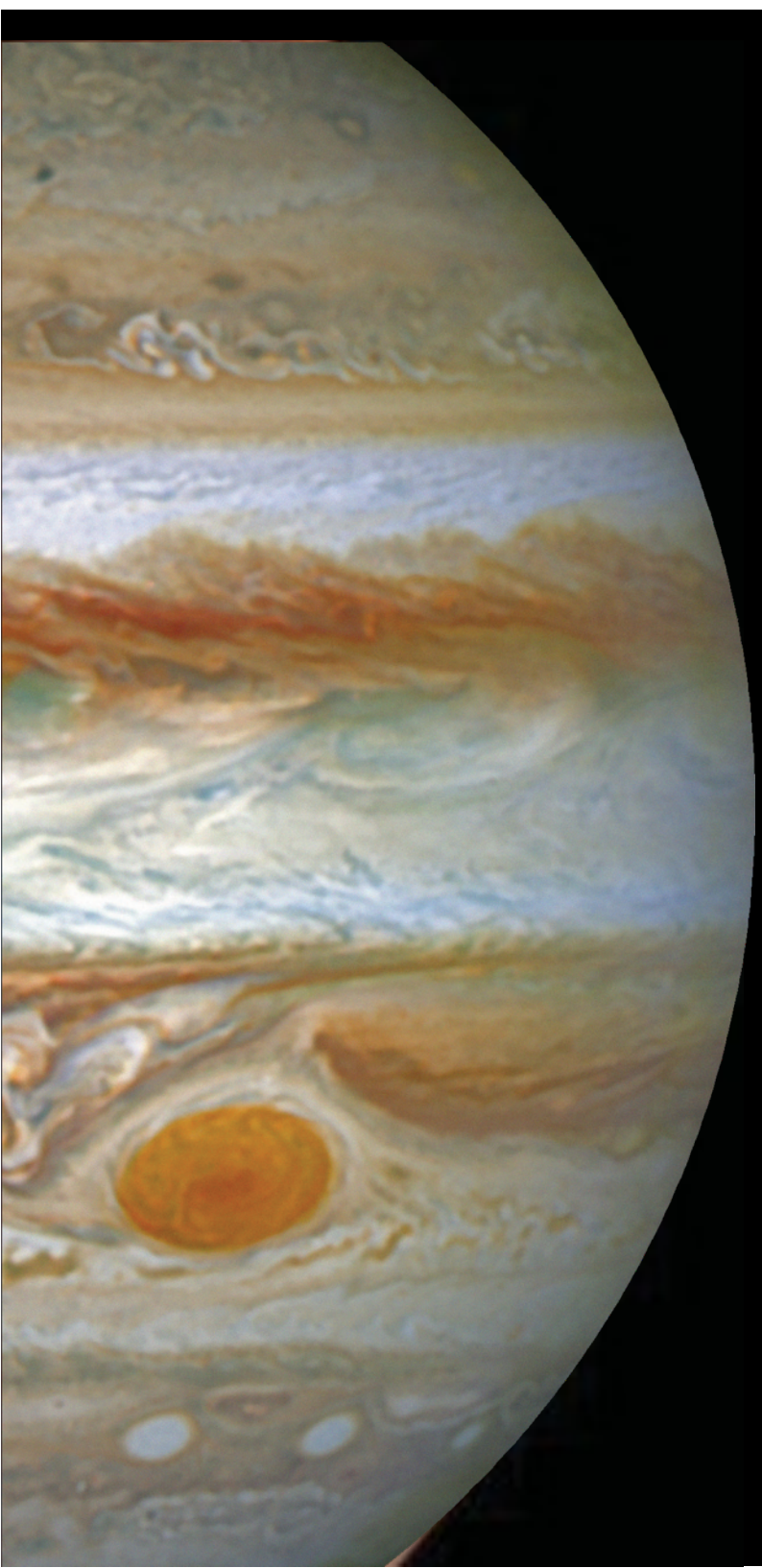


Christina Richey  
Jet Propulsion Laboratory,  
California Institute of Technology  
@PlanSciCRichey





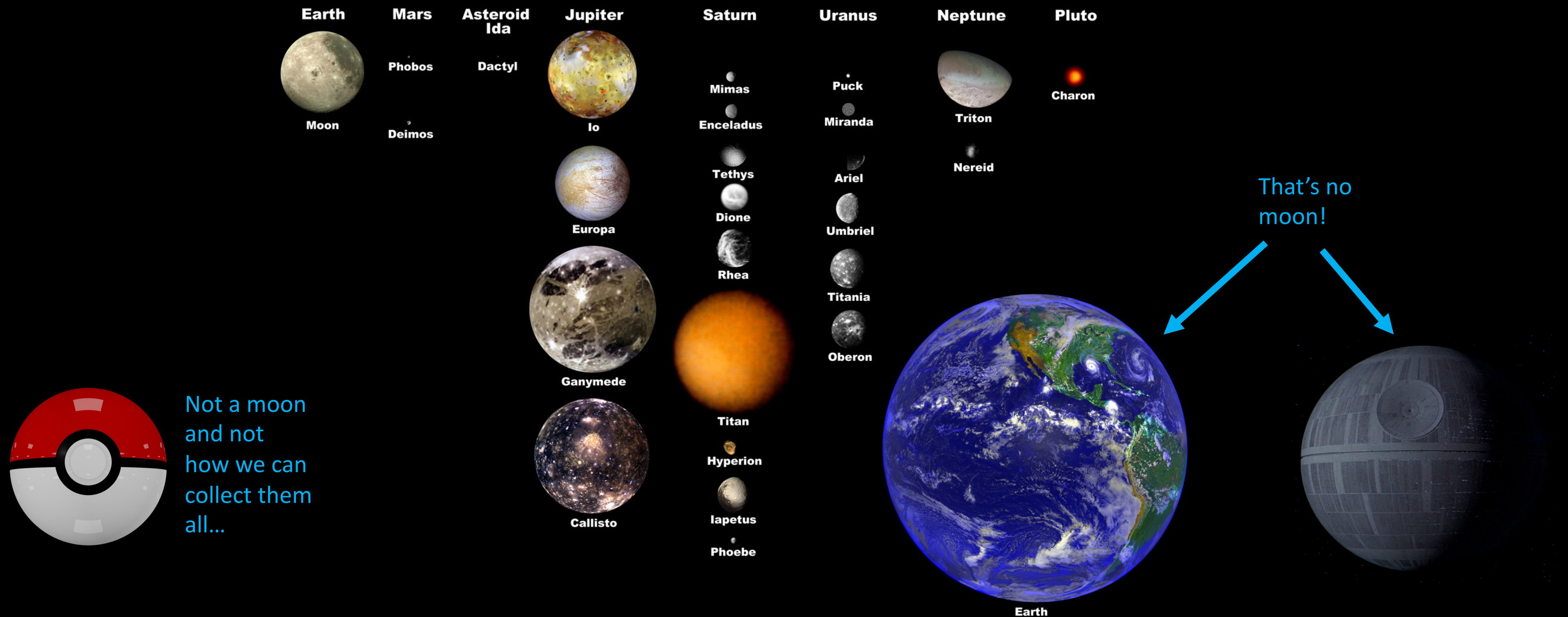
# Agenda Story Board



1. Once upon a time there was a group of planetary bodies called Ocean Worlds.
2. Every day scientists studied these Ocean Worlds to understand their composition and awesomeness.
3. One day scientists focused their sights on one of those Icy Worlds, Europa.
4. Because of that NASA formed a mission that would be known as the Europa Clipper Mission.
5. Because of that the mission began to go through the formulation and build process.
6. ~~Until finally~~... Actually, this story is just beginning, but I'll tell you about where we are as a team, and how we operate as "one team"!

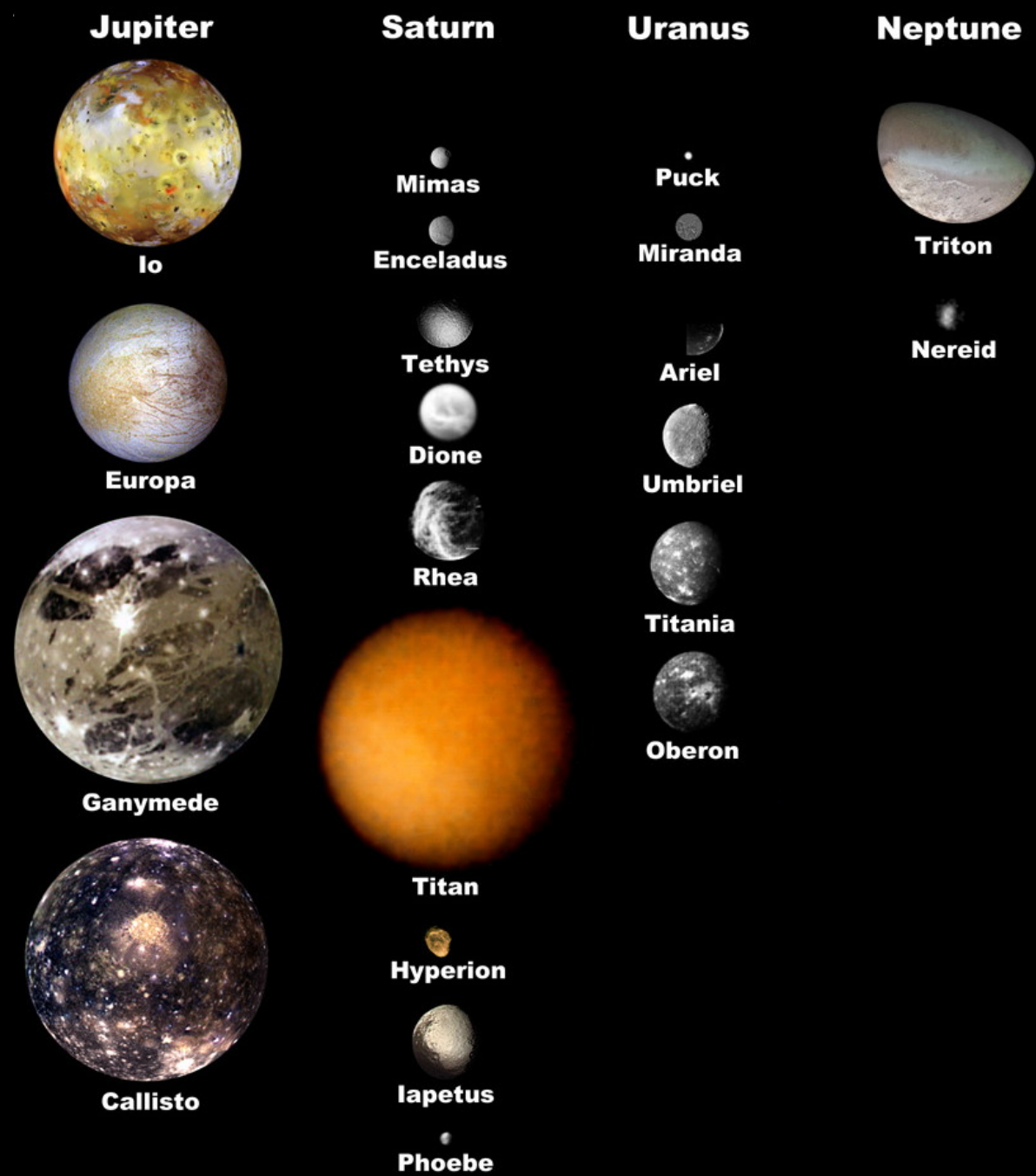


# Major Moons of the Solar System



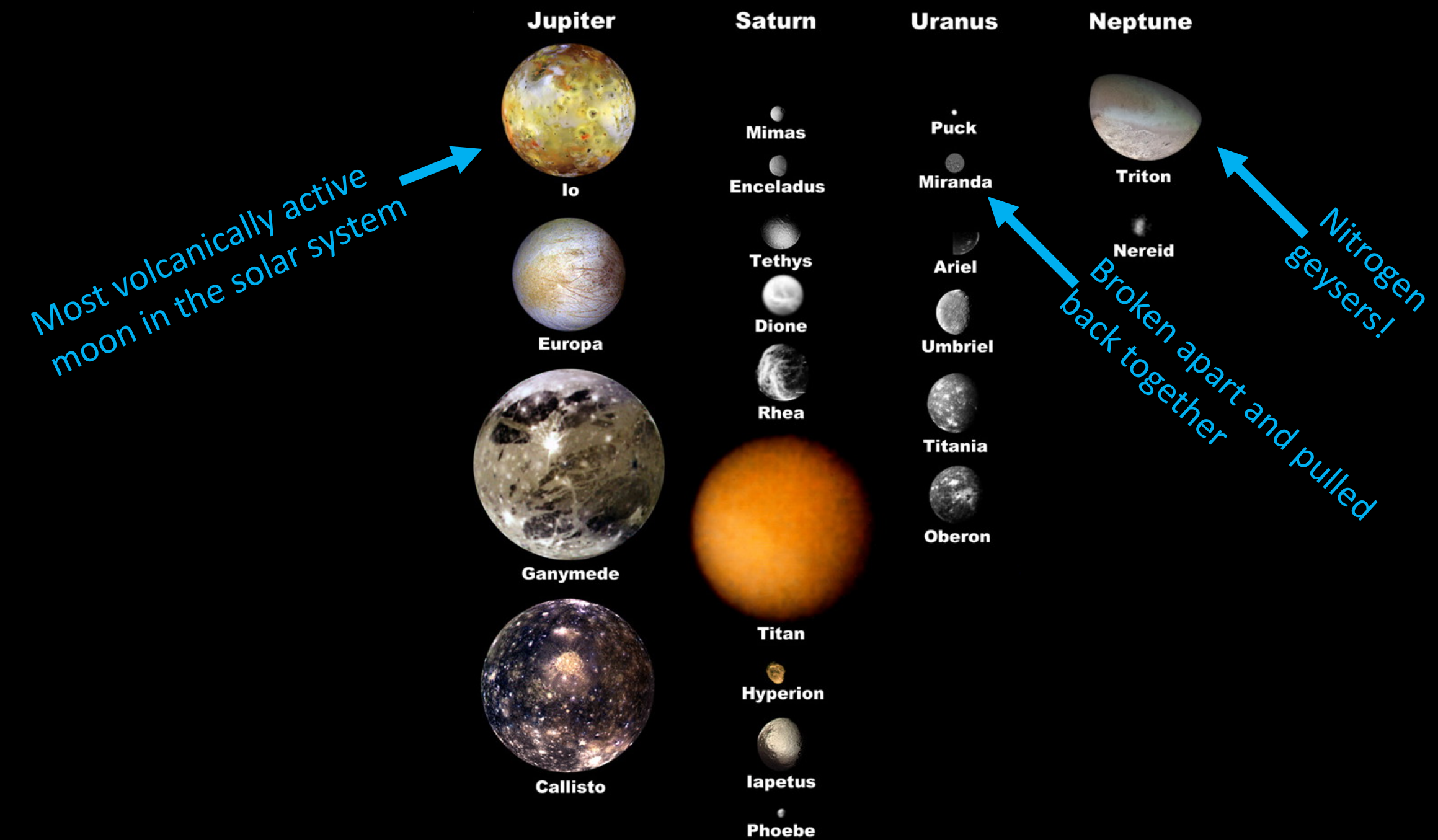


# Major Moons of the Outer Solar System



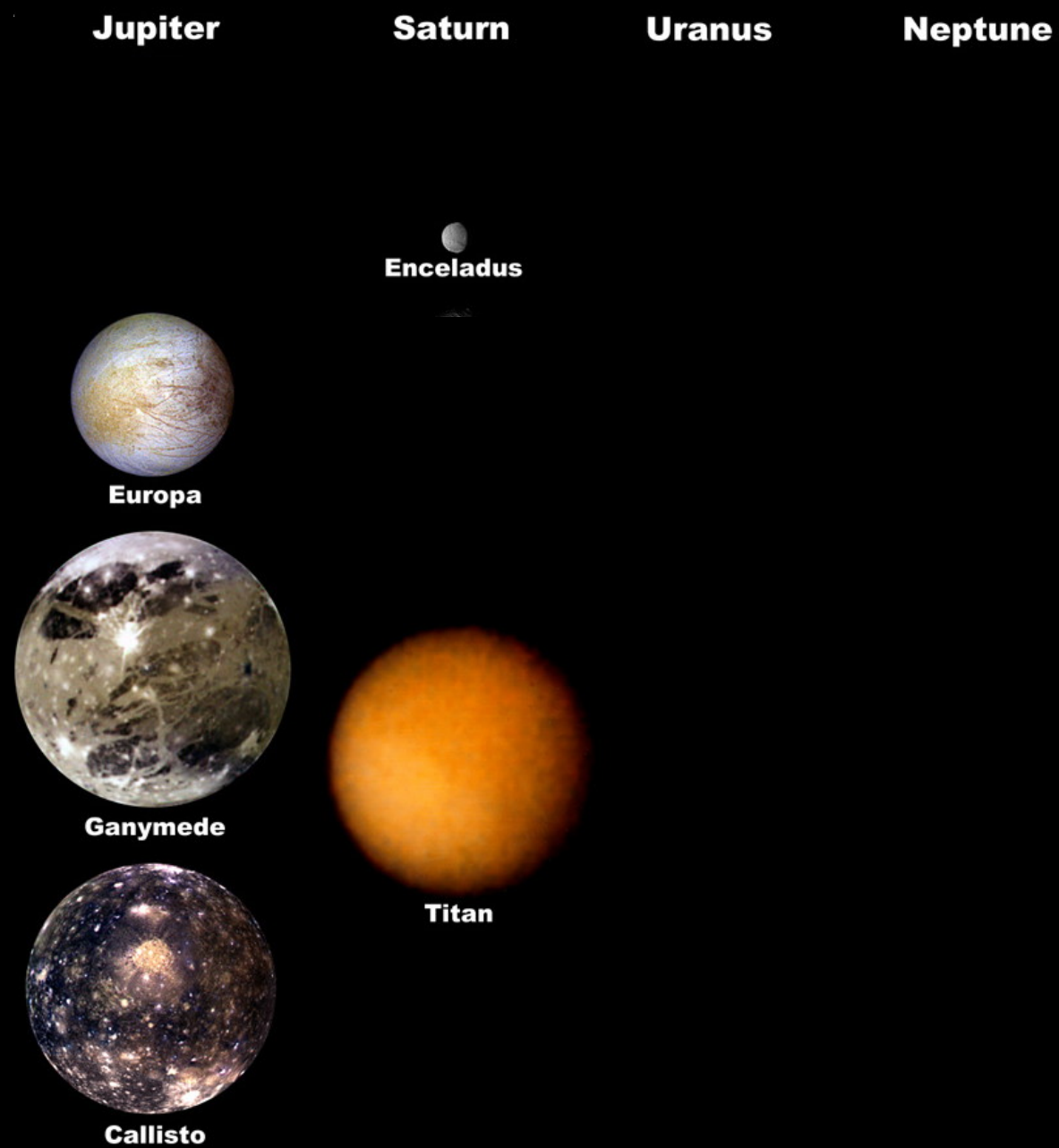


# Things we won't be discussing today....



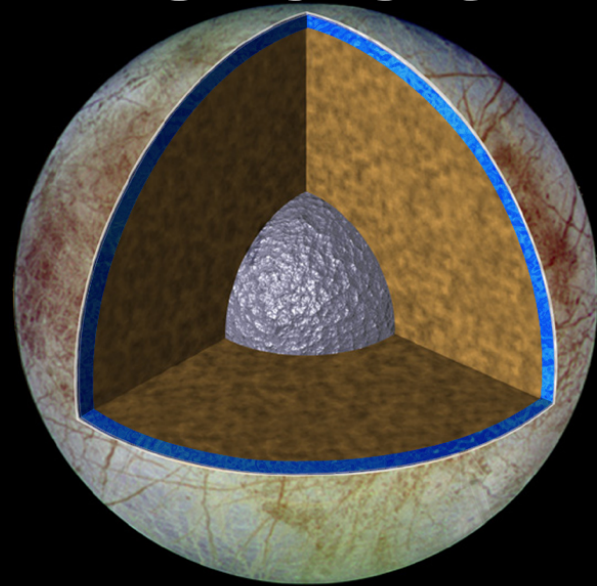


# Ocean Worlds of the Outer Solar System





# Oceans, Oceans Everywhere

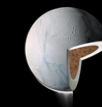


**Europa**

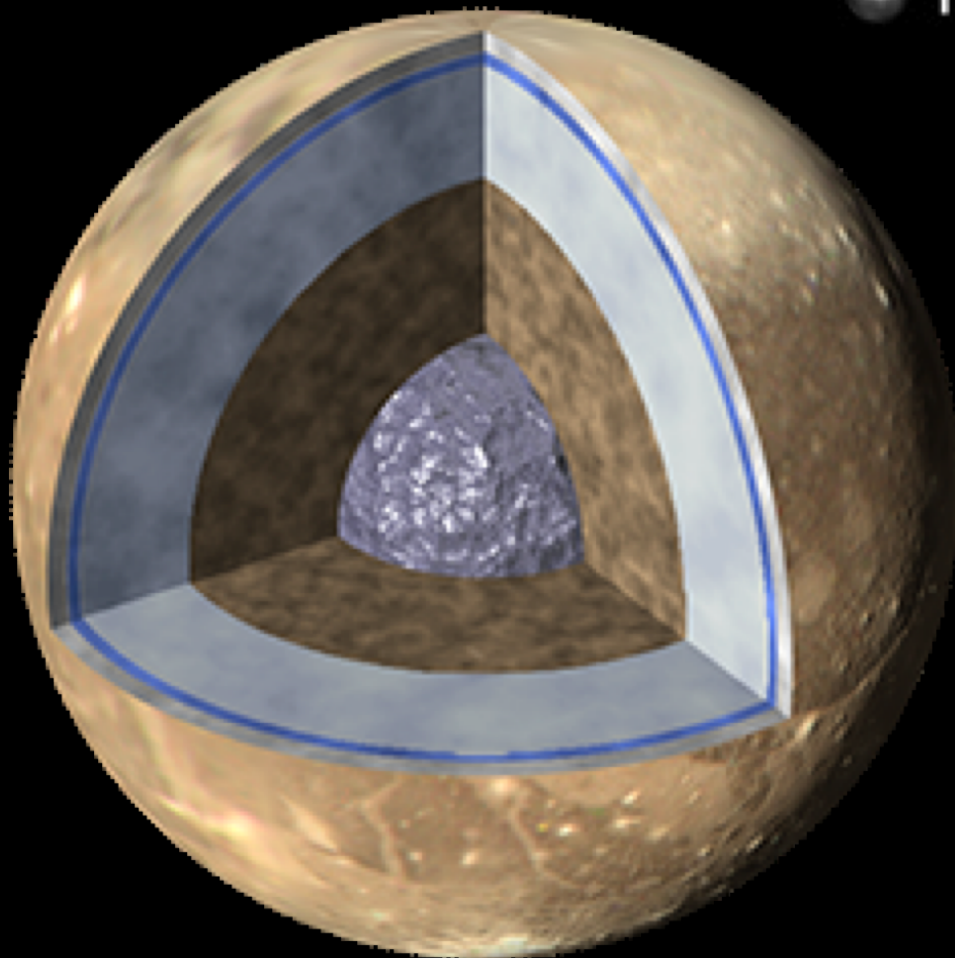
- ice
- water
- rock
- metal



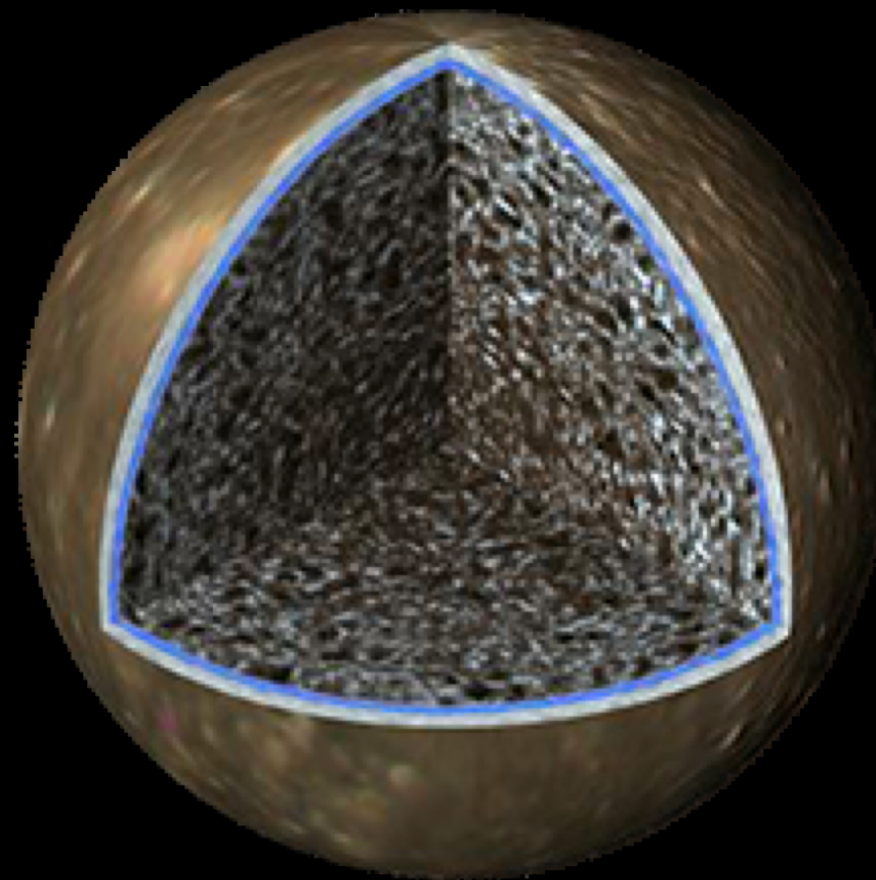
**Earth**



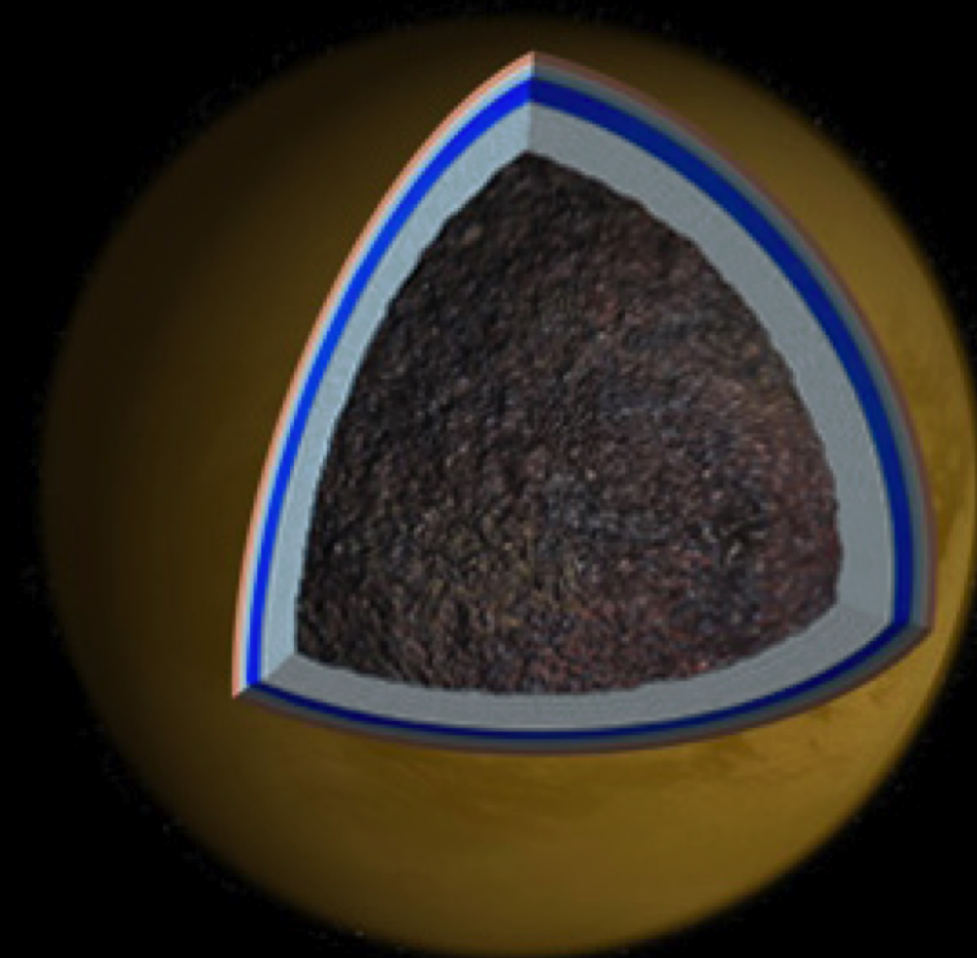
**Enceladus**



**Ganymede**



**Callisto**



**Titan**

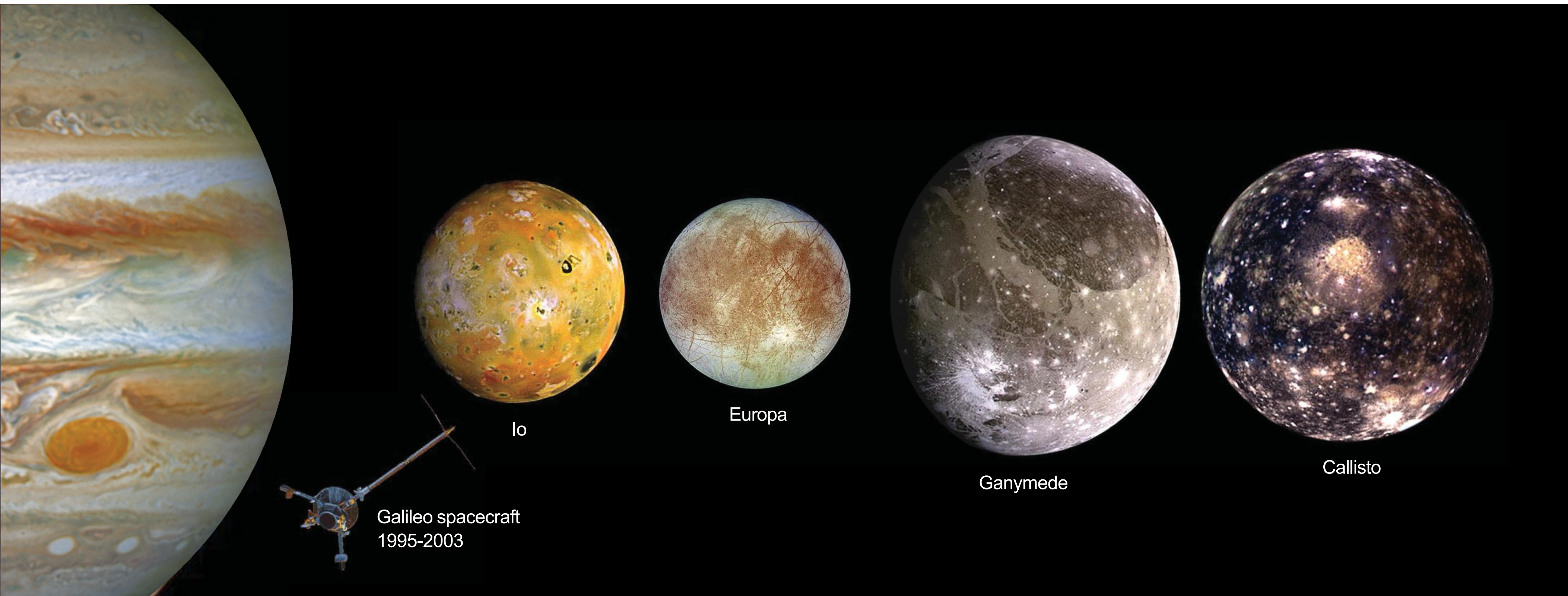


# Ocean Worlds of the Outer Solar System





# The Galilean Satellites of Jupiter



Galileo spacecraft  
1995-2003



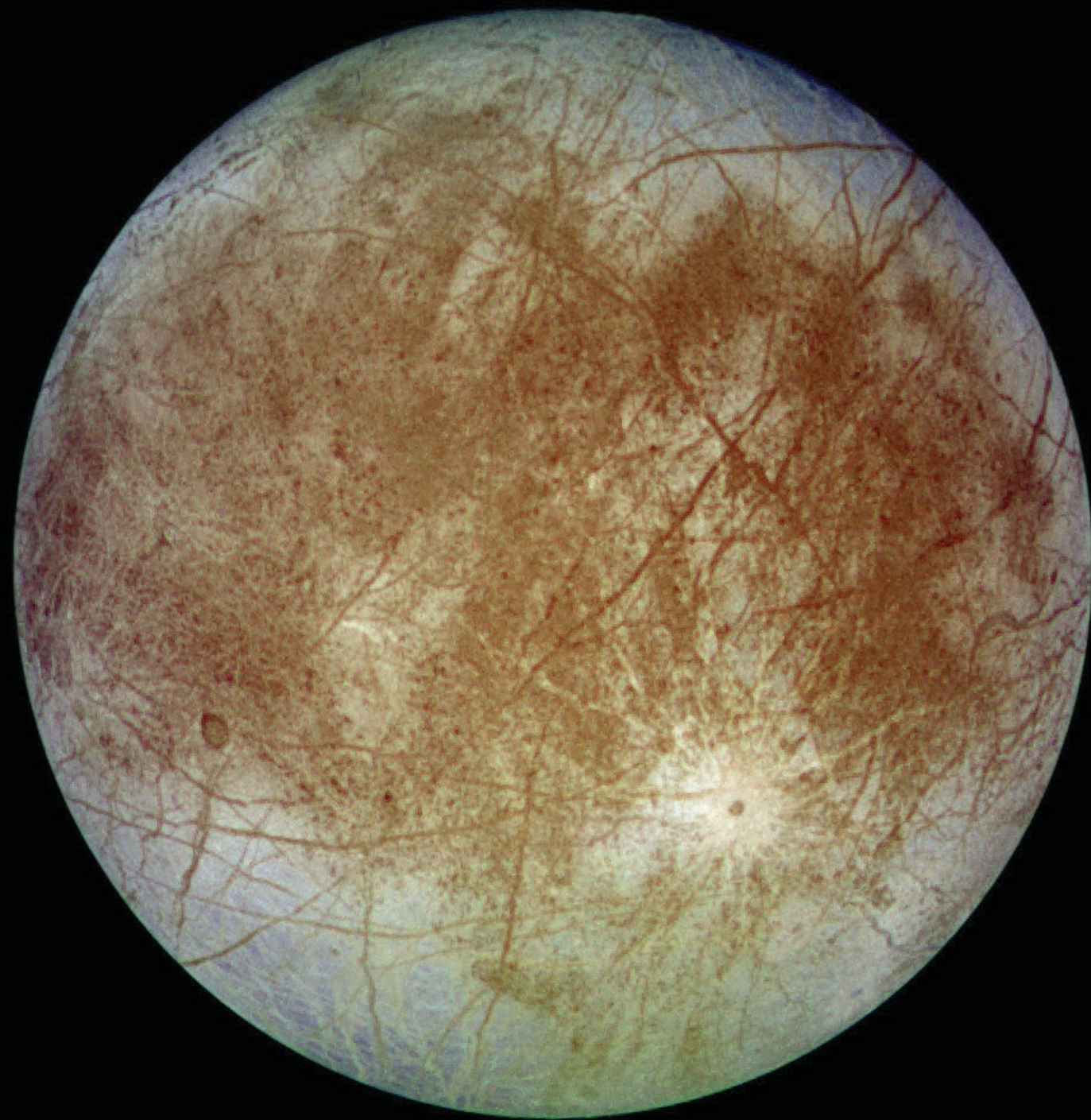
# Some basic planetary science...

- **Cratering can tell us how old a surface is**
  - A lot of craters (craters on top of craters) = old
- **How do we know what's inside a moon anyway?**
  - Magnetometer
  - Radio Science Gravity data
- **Planetary differentiation (big things do this)**
  - the process of separating out different constituents of a planetary body as a consequence of their physical or chemical behavior.
  - The body develops into compositionally distinct layers where the denser material sink to the center
- **Tidally locked**
  - A moon that rotates in the same amount of time that it orbits. The Earth's Moon does this
  - Sometimes we say 1:1 synchronous rotation
  - The same face of the moon faces the planet all the time
- **If you are closer to the main body you orbit faster**



# Europa

- Tidally locked, rotates 3.5 days
- Fully differentiated
- Surface temp = 50~100 K
- An amazing complex array of surface features: Ridged plains, Chaos, Lenticule, Cycloids, Very few craters, Few multi-ring structures



Ridged plains



Chaos



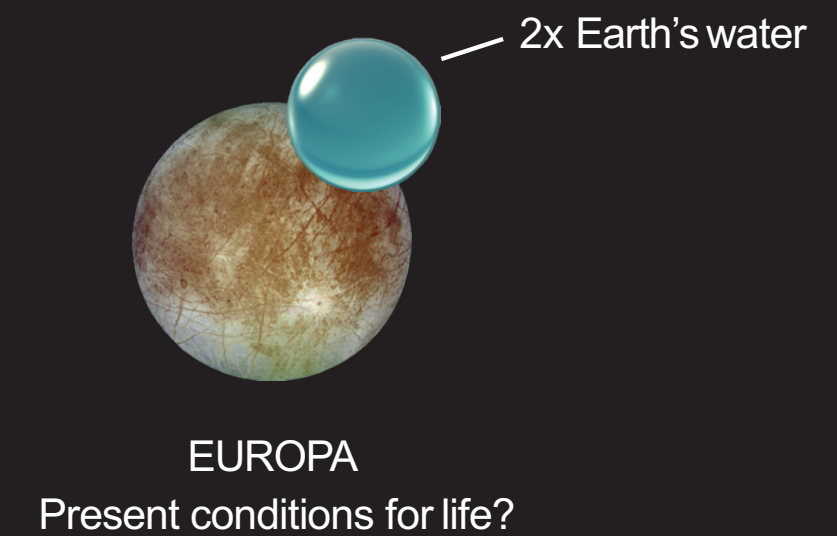
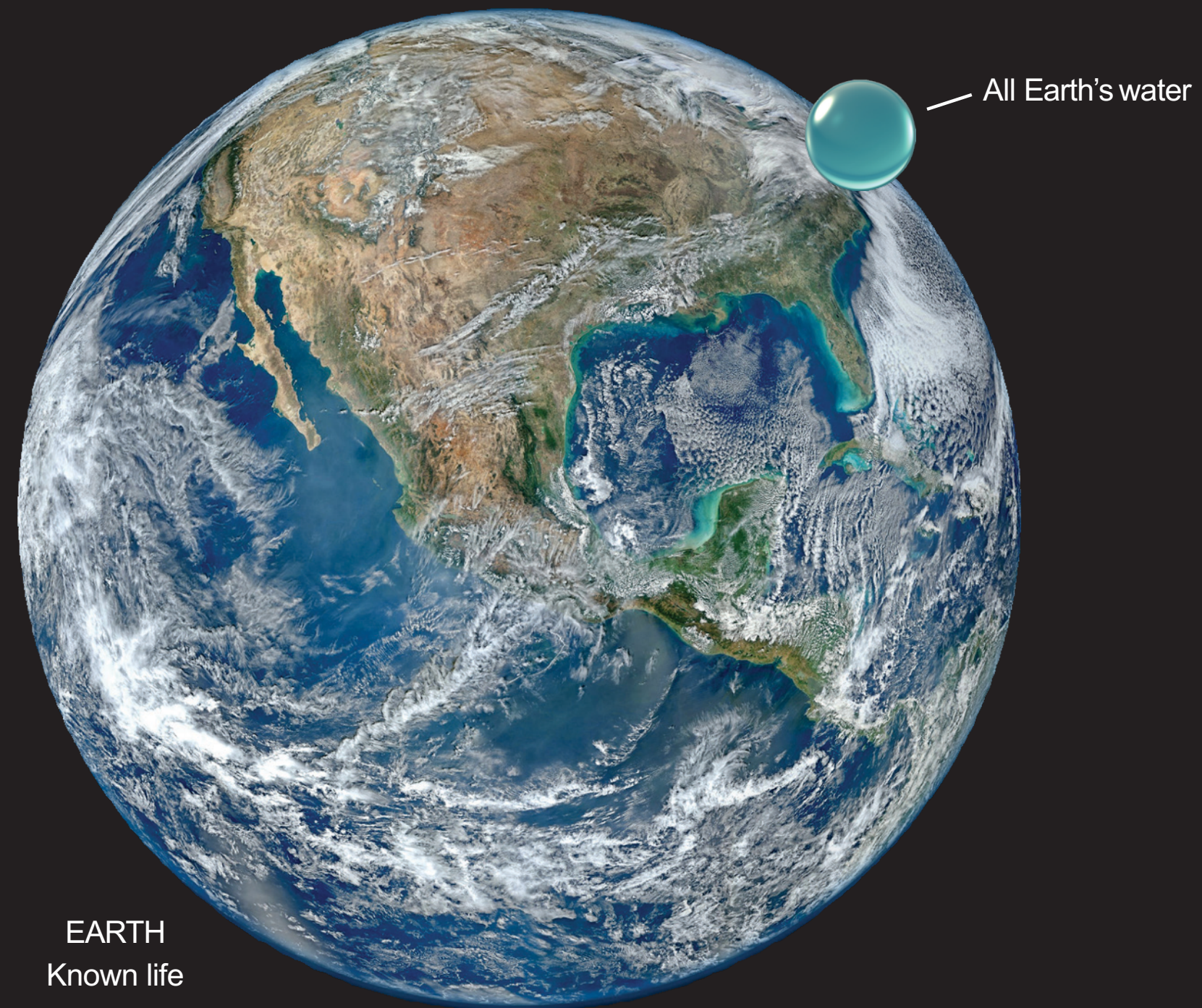
Craters



Lenticulae

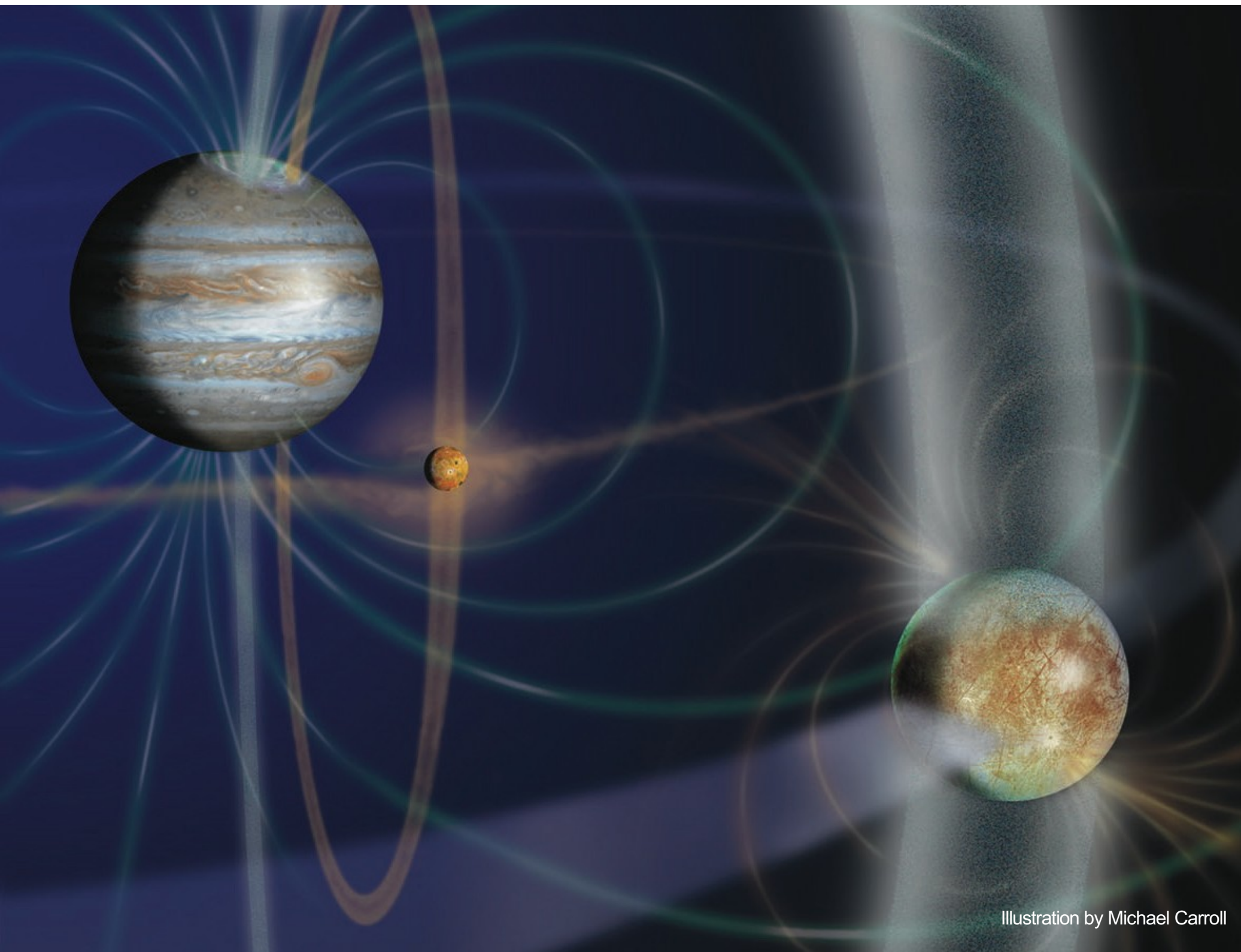


# Europa: More Water Than Earth



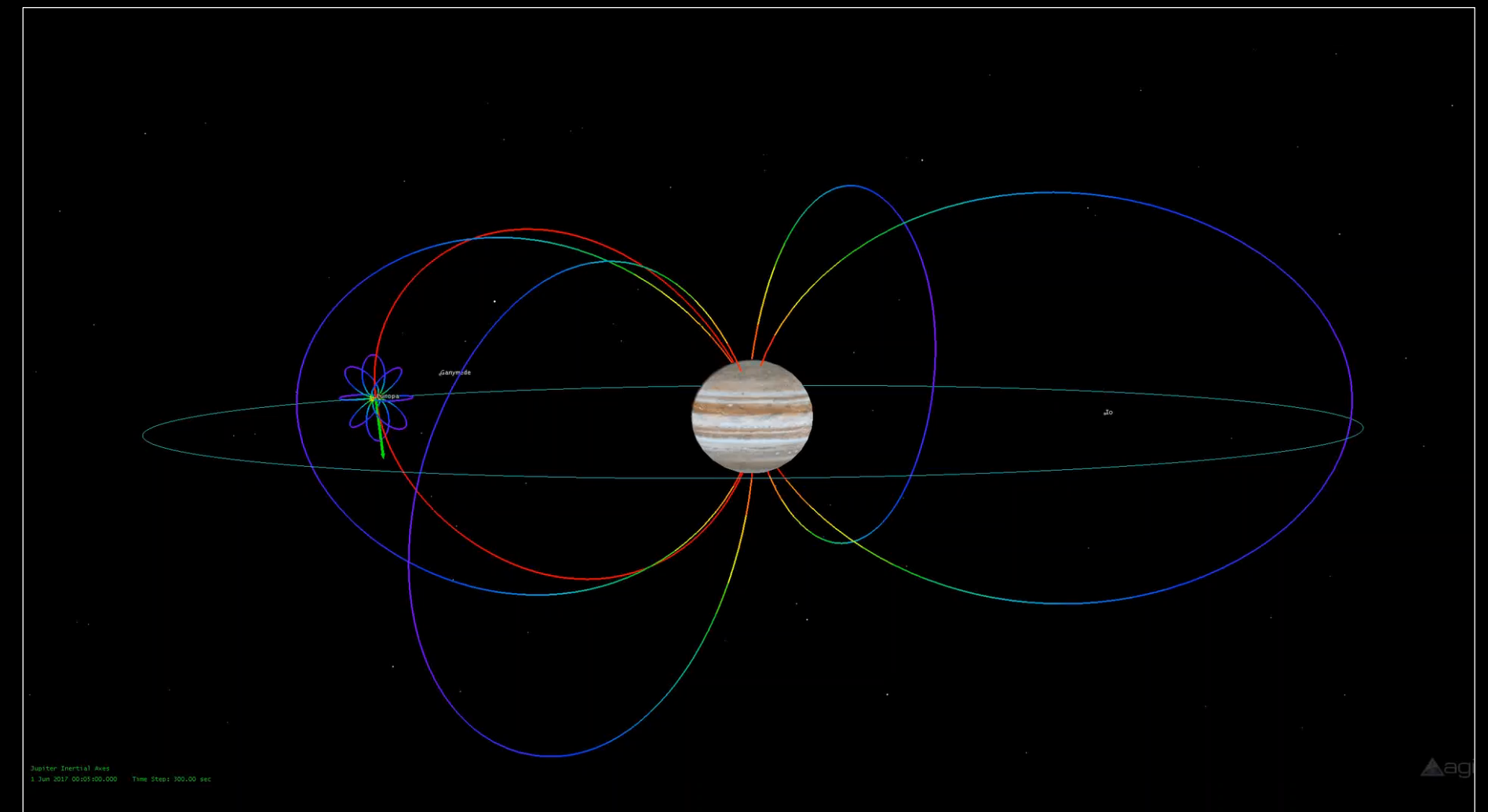


# Europa's Magnetic Personality



## Europa's Induced Magnetic Field

- Field Line at Europa
- Europa Orbit Plane
- Vector at Europa

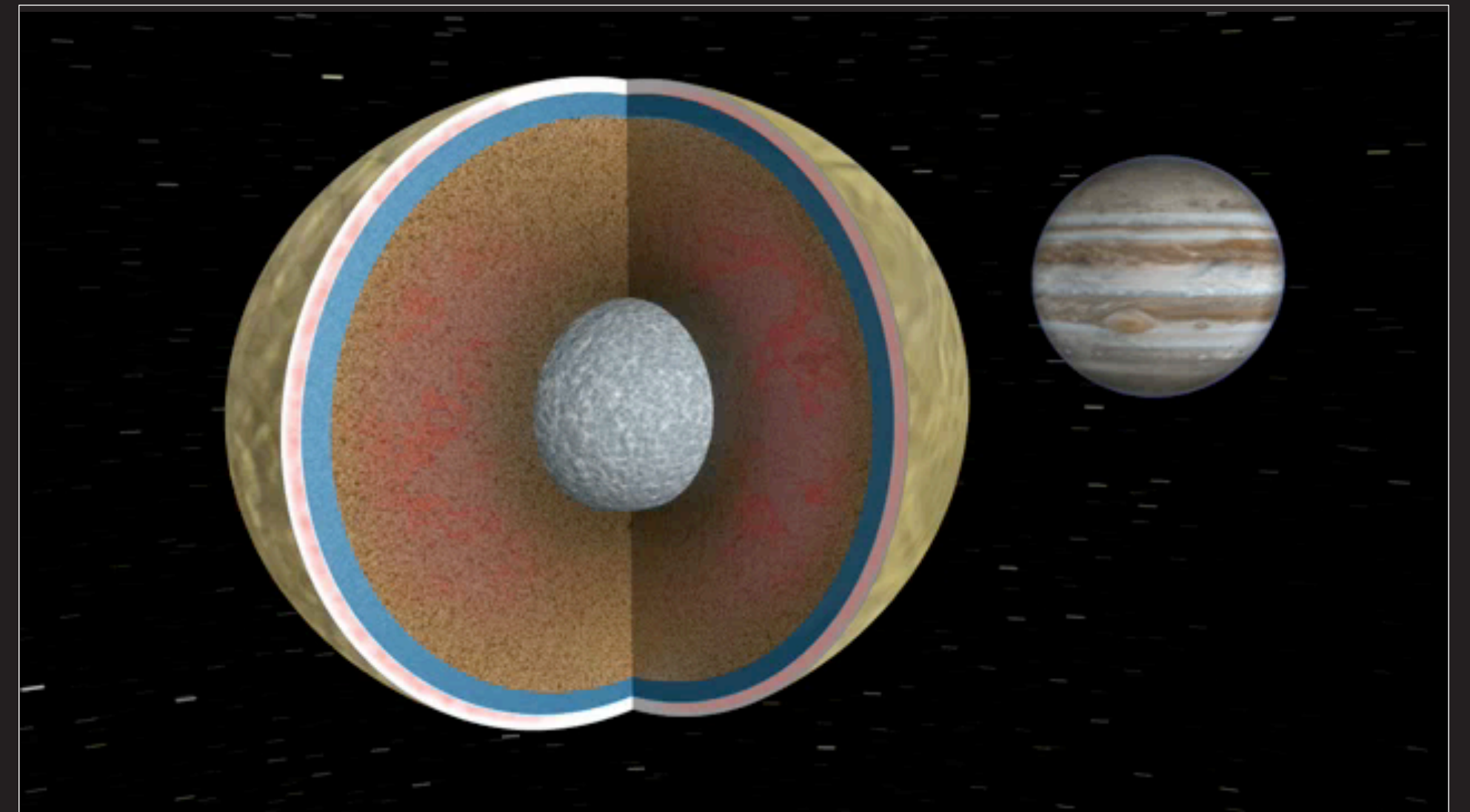




# Tidal Flexing → Tidal Heating



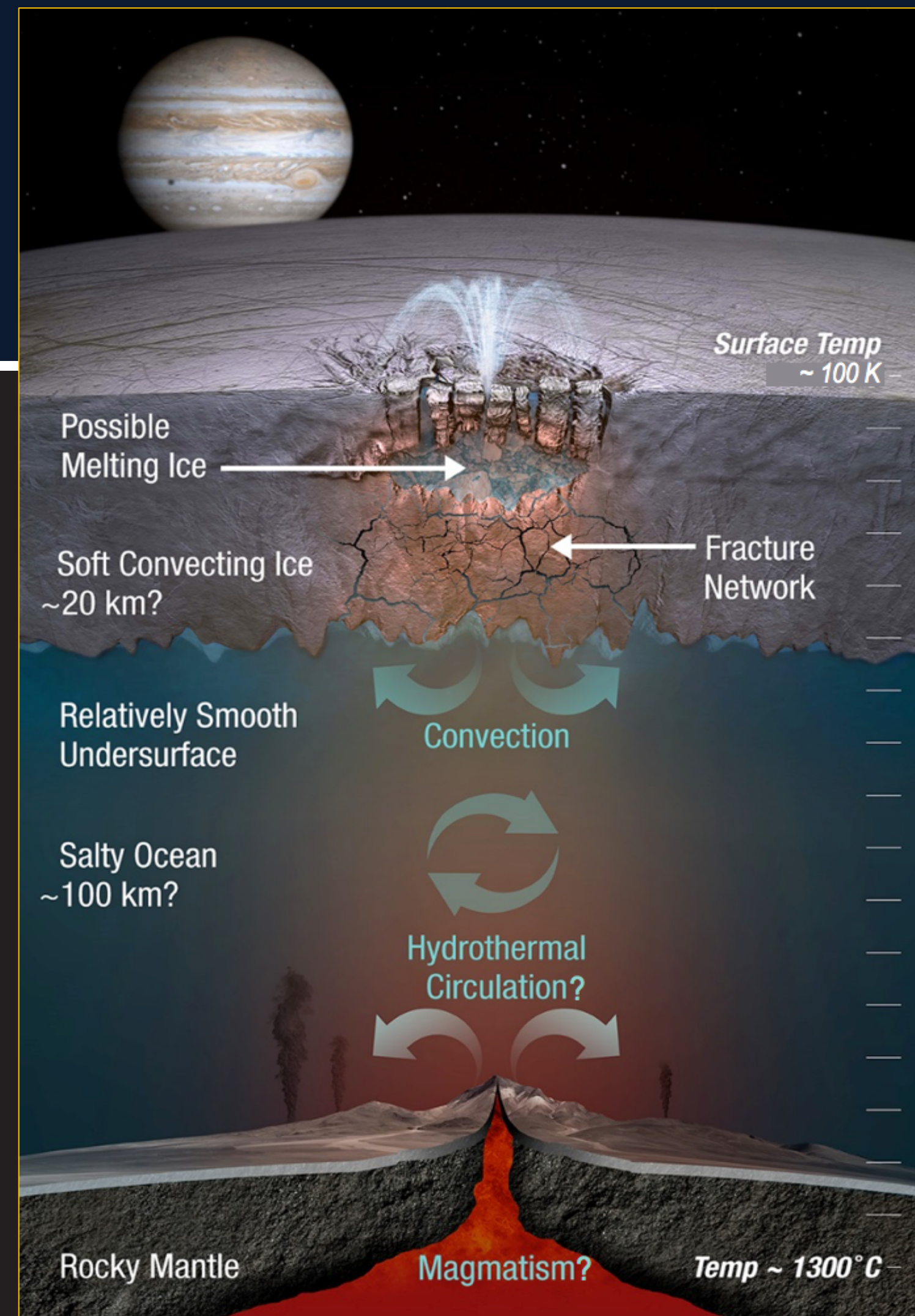
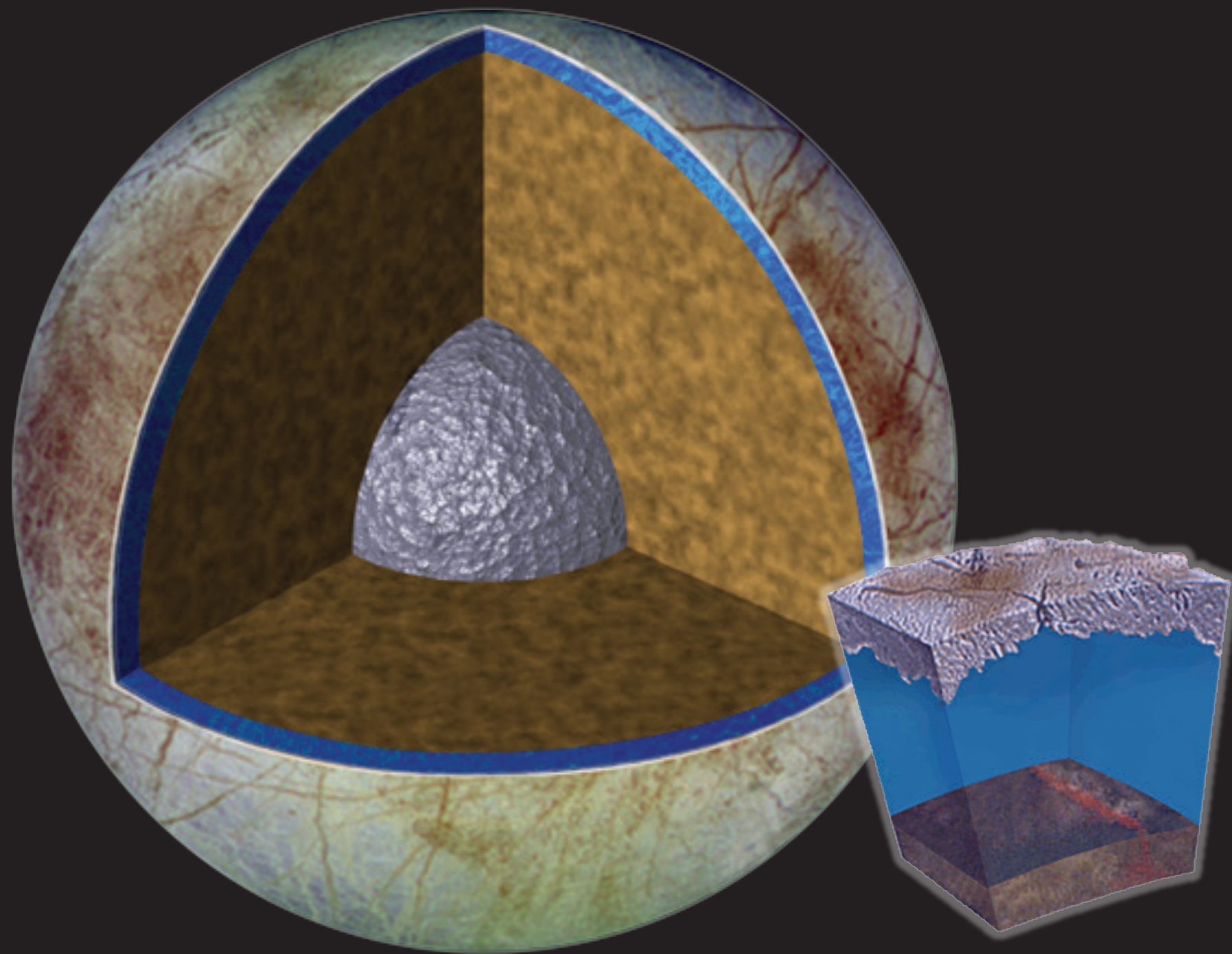
Not to Scale



Not to Scale



# Europa's Interior

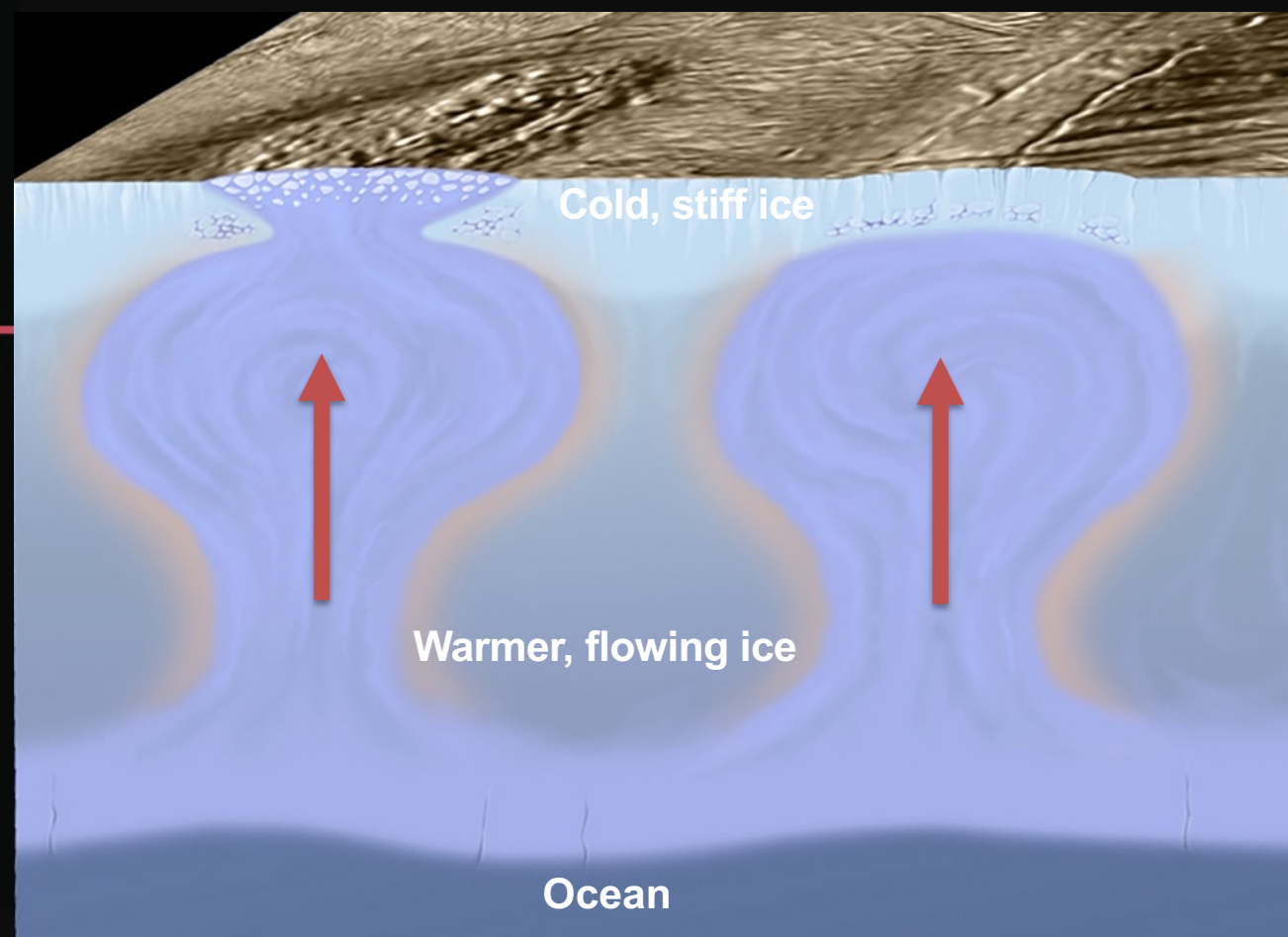
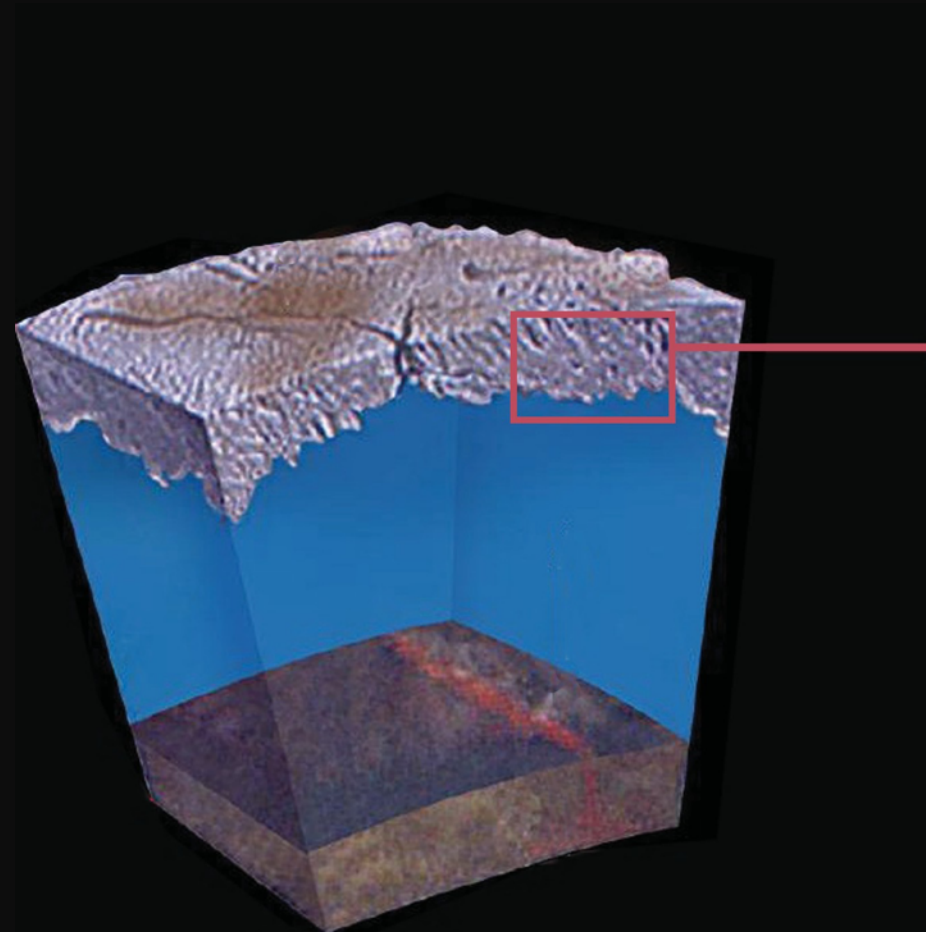




# Europa Convection



Lenticulae

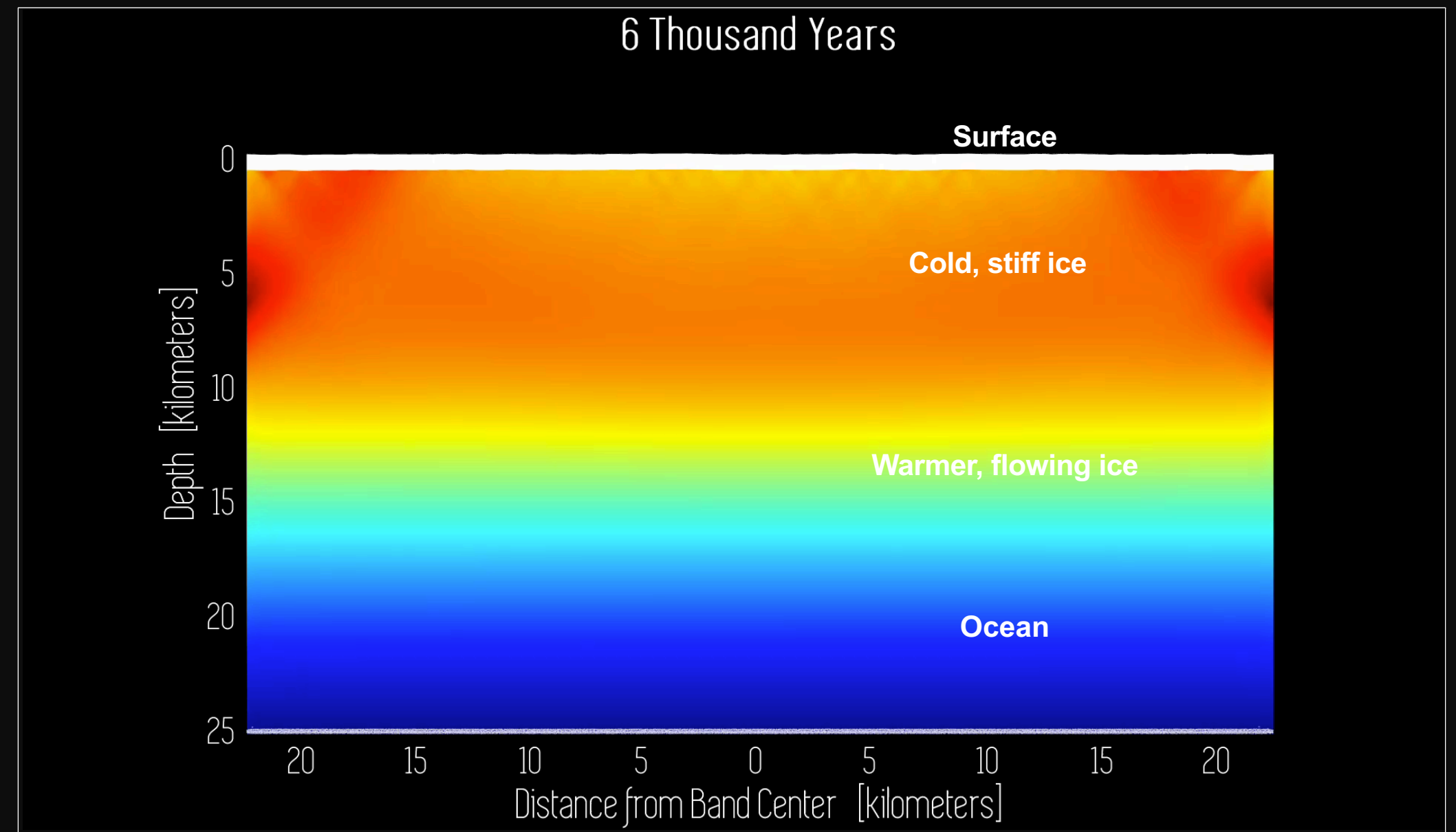




# Bands

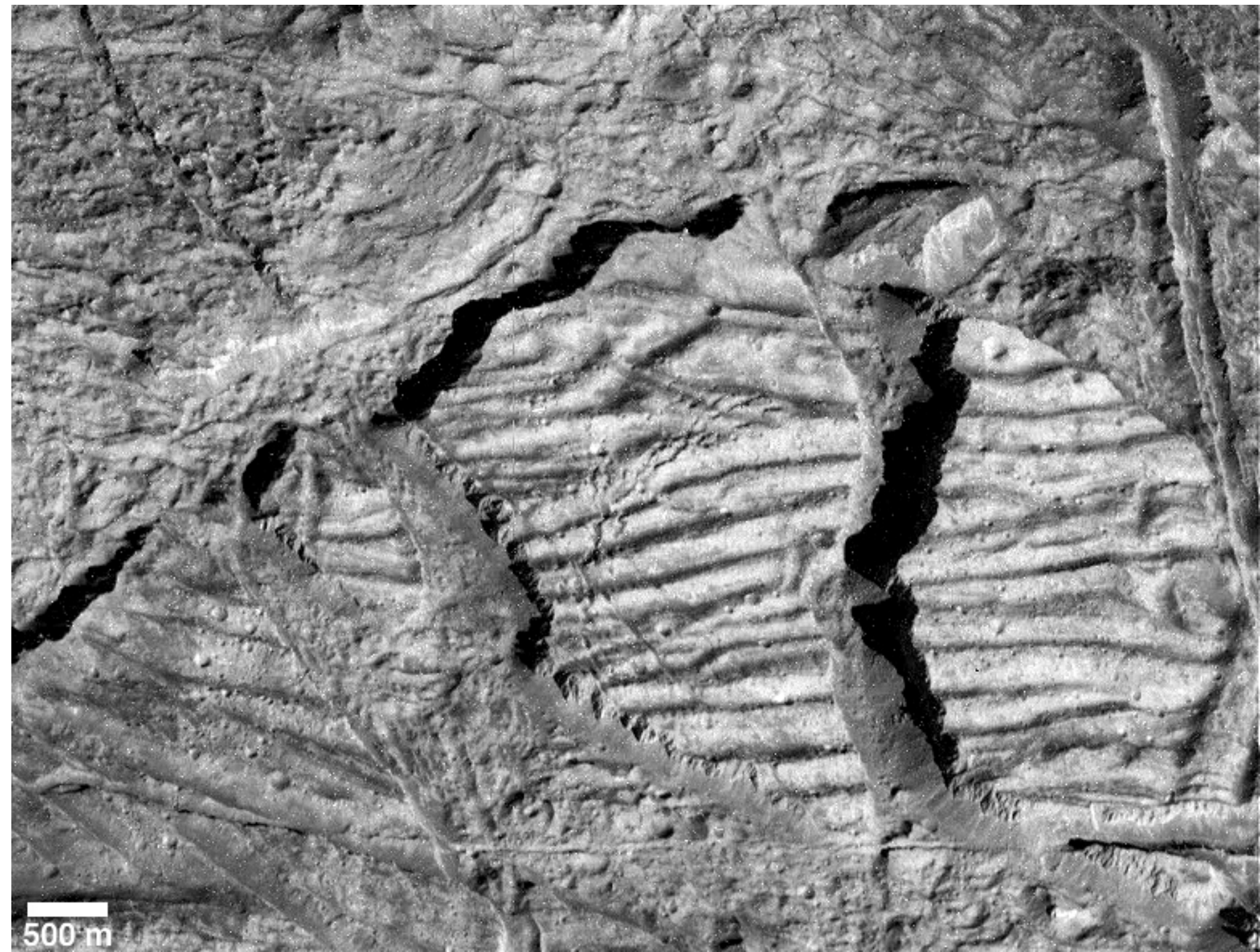


Reddish Bands



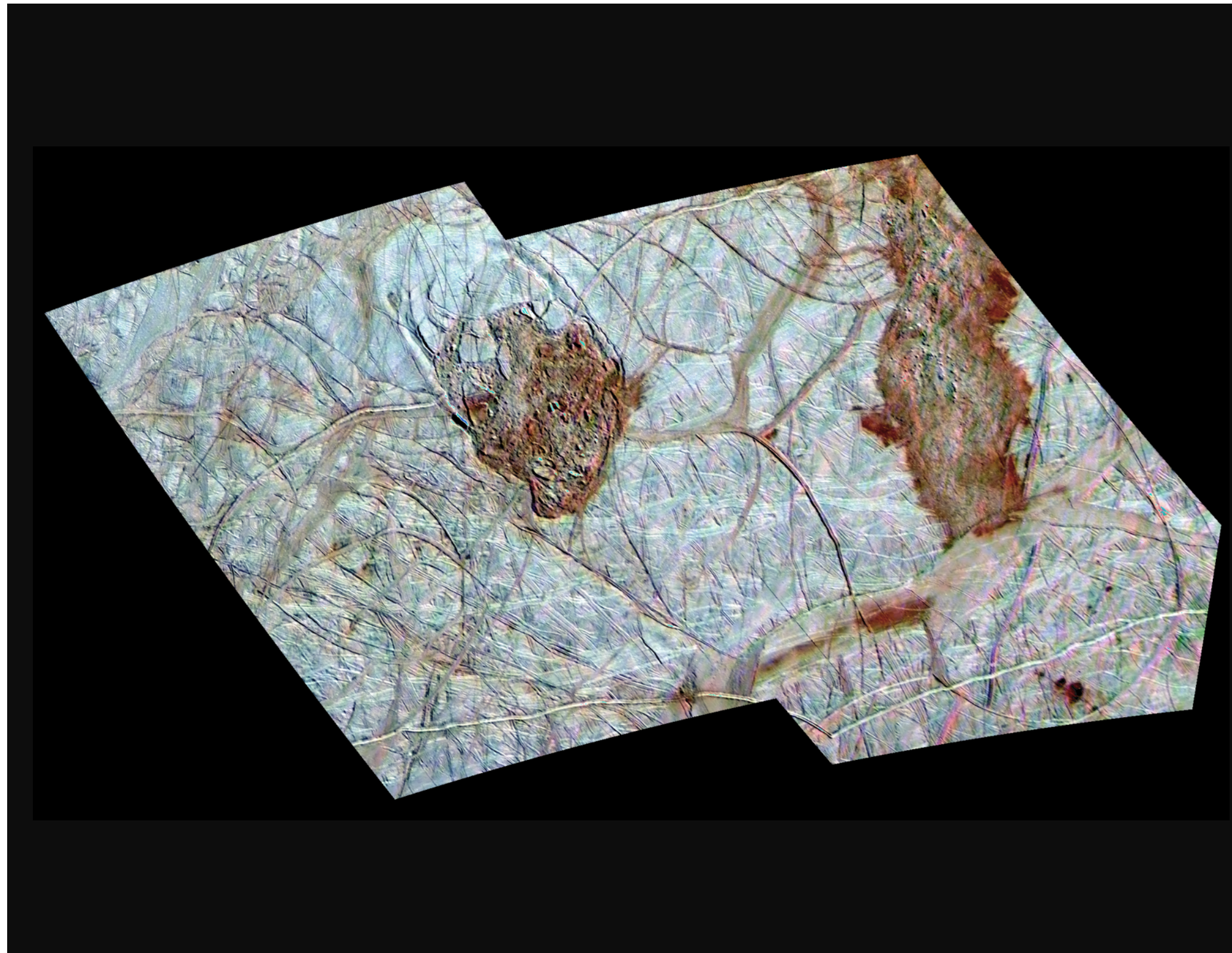
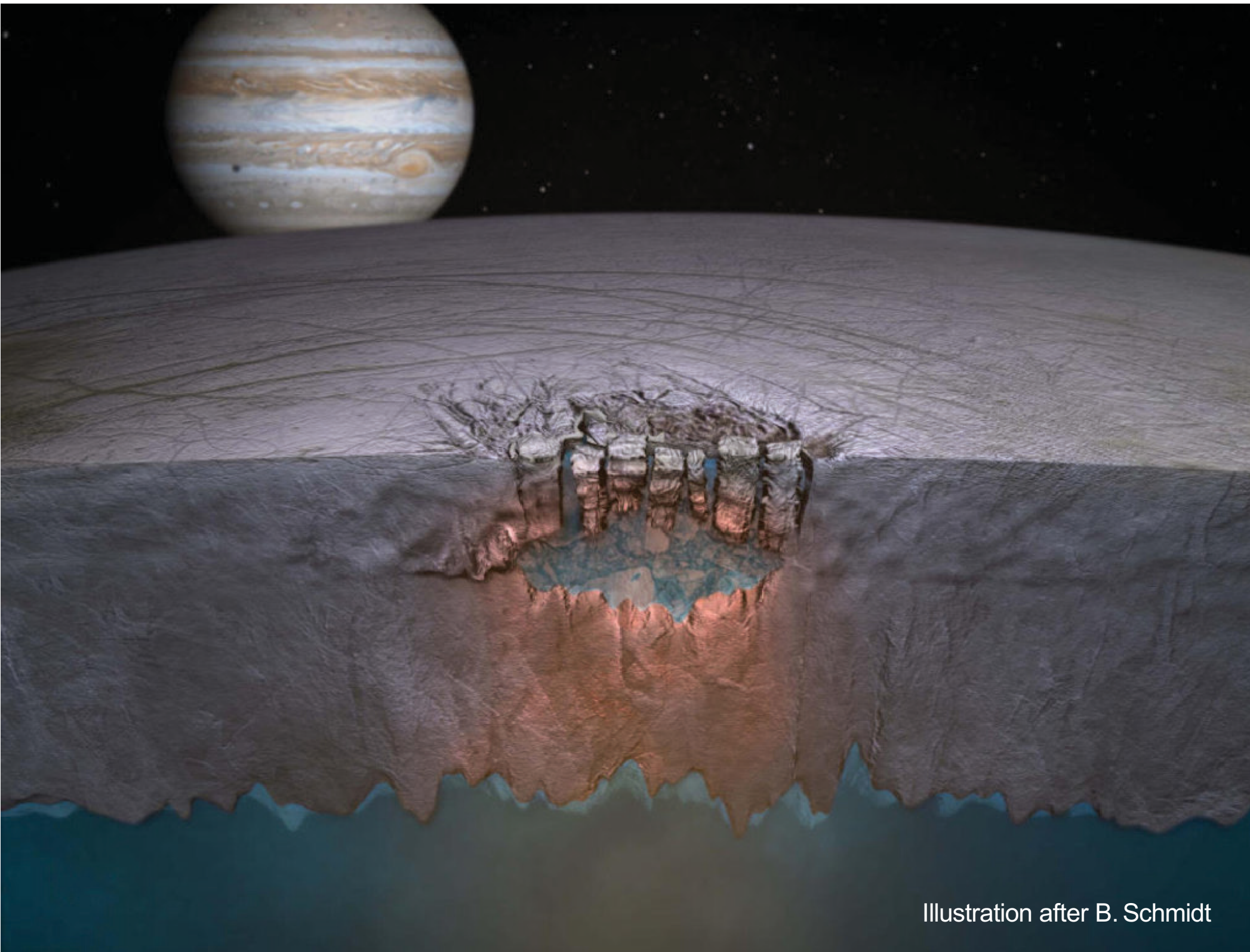


# Chaos





# Chaos





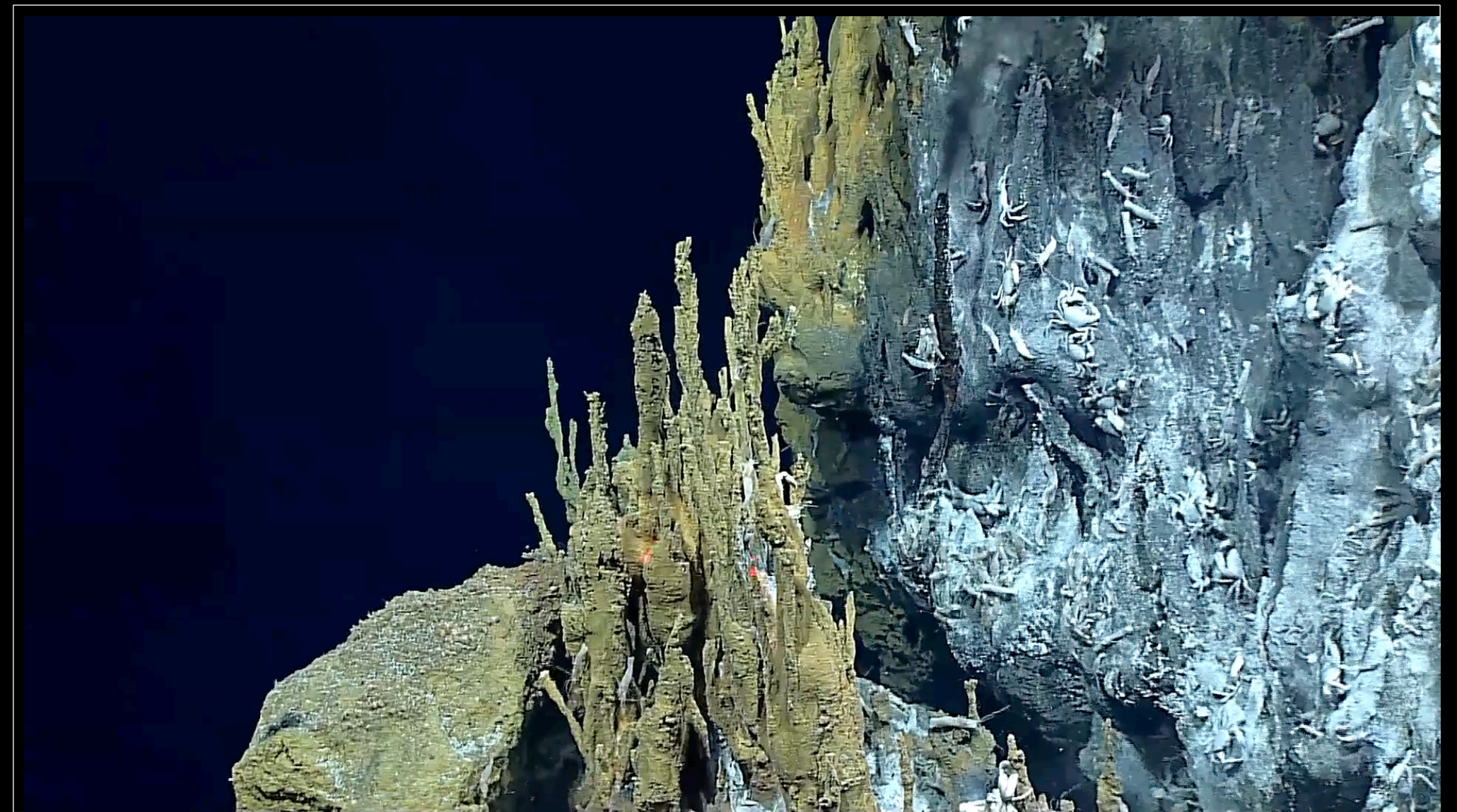
# Ingredients for Life?

**WATER:** Much more than all of Earth's oceans

**ESSENTIAL ELEMENTS:** From formation and impacts

**CHEMICAL ENERGY:** From above and below

**STABILITY:** "Simmering" for 4 billion years

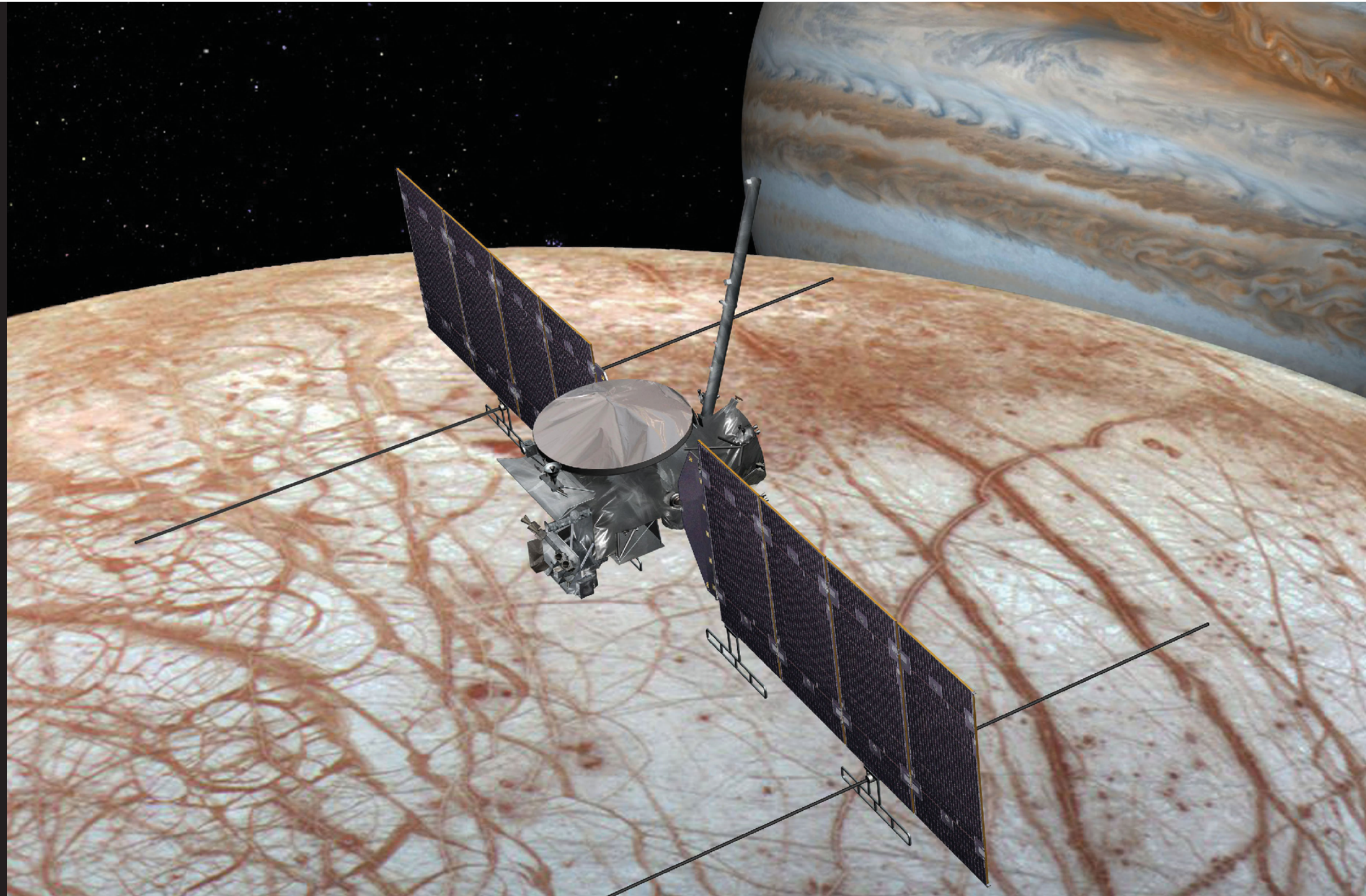


Hydrothermal Vent at Bottom of Earth's Ocean

Video courtesy of the NOAA Office of Ocean Exploration and Research, 2016 Deepwater Exploration of the Marianas



# NASA's Europa Clipper Mission

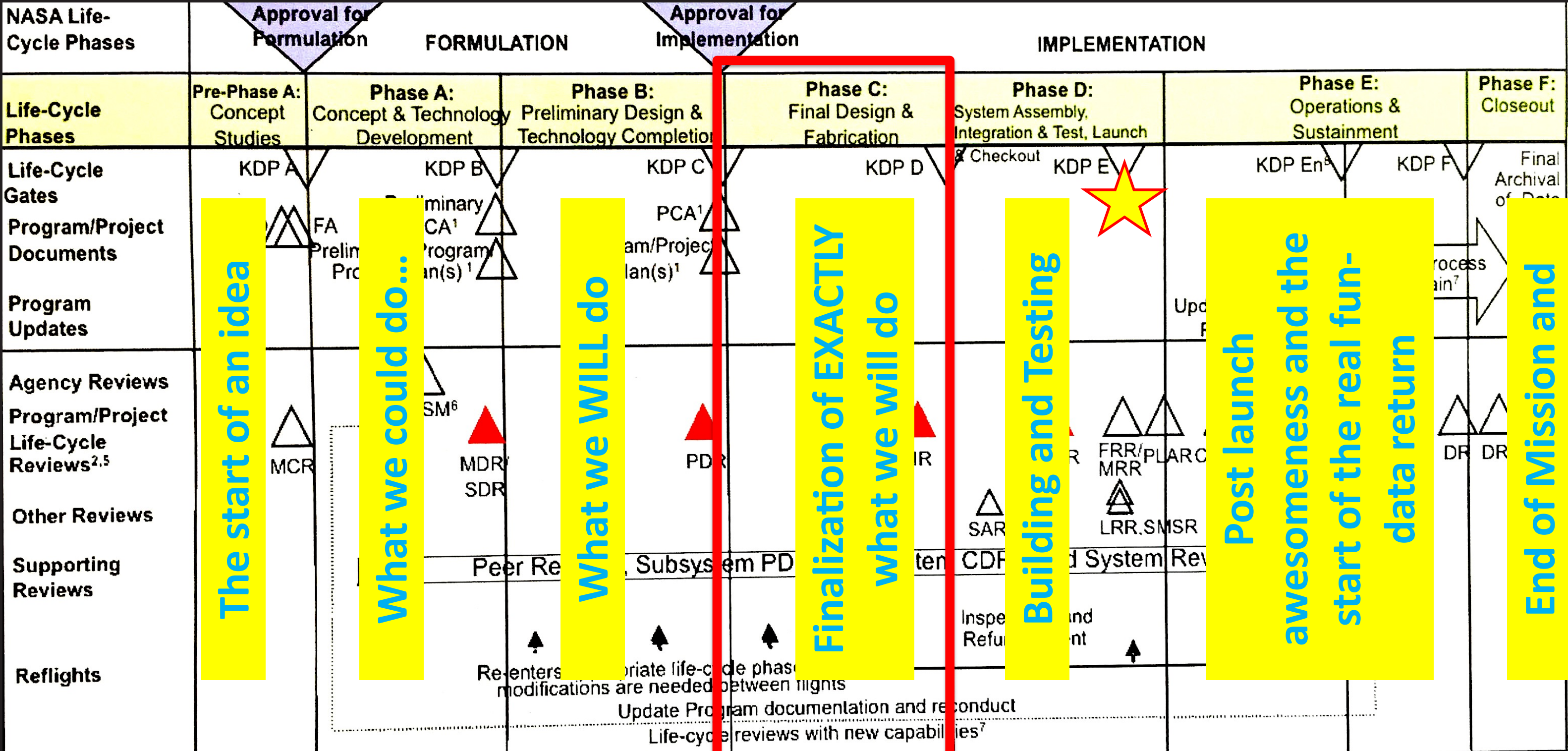




# Mission Lifecycle

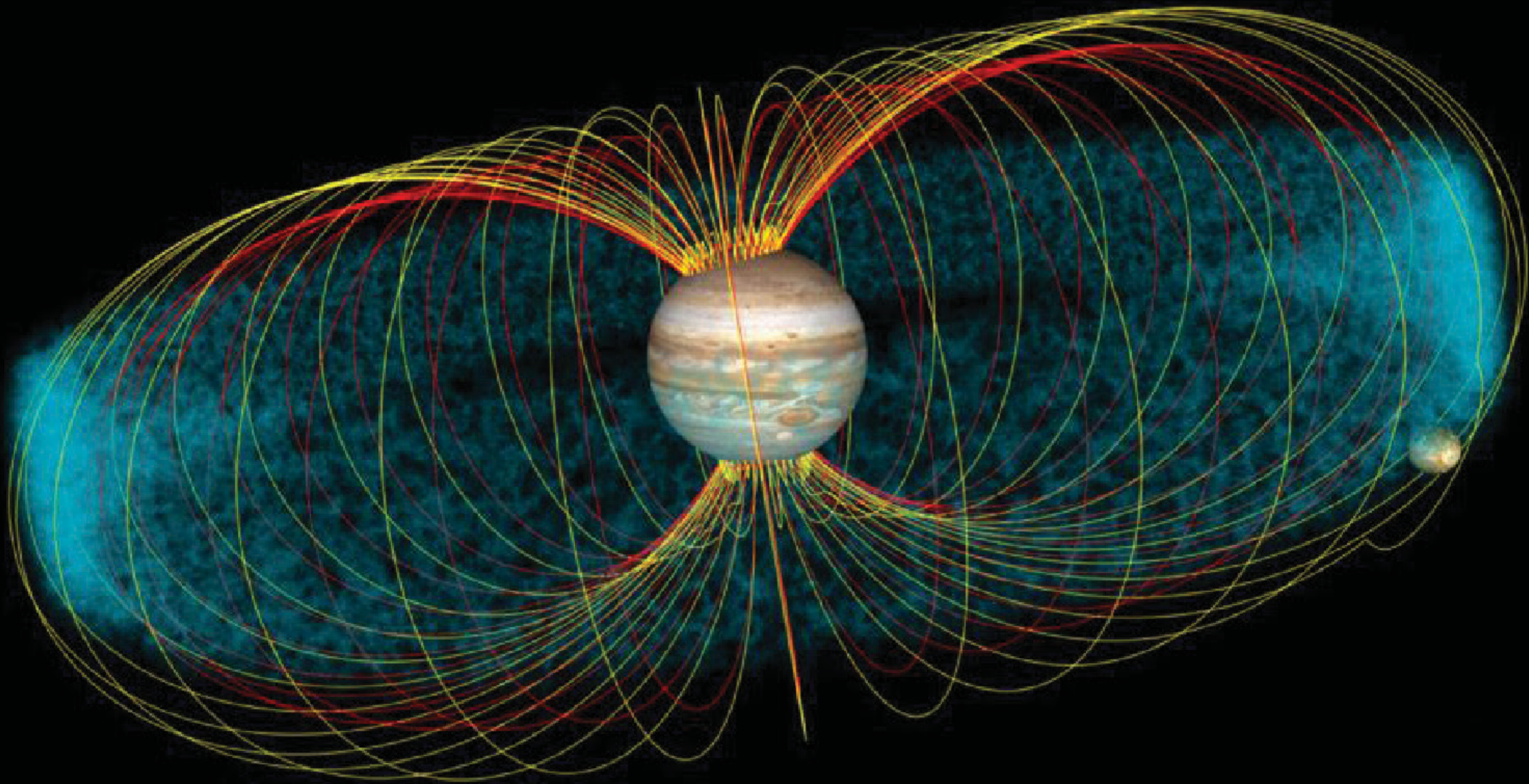


Confirmation: June 21, 2019!!!



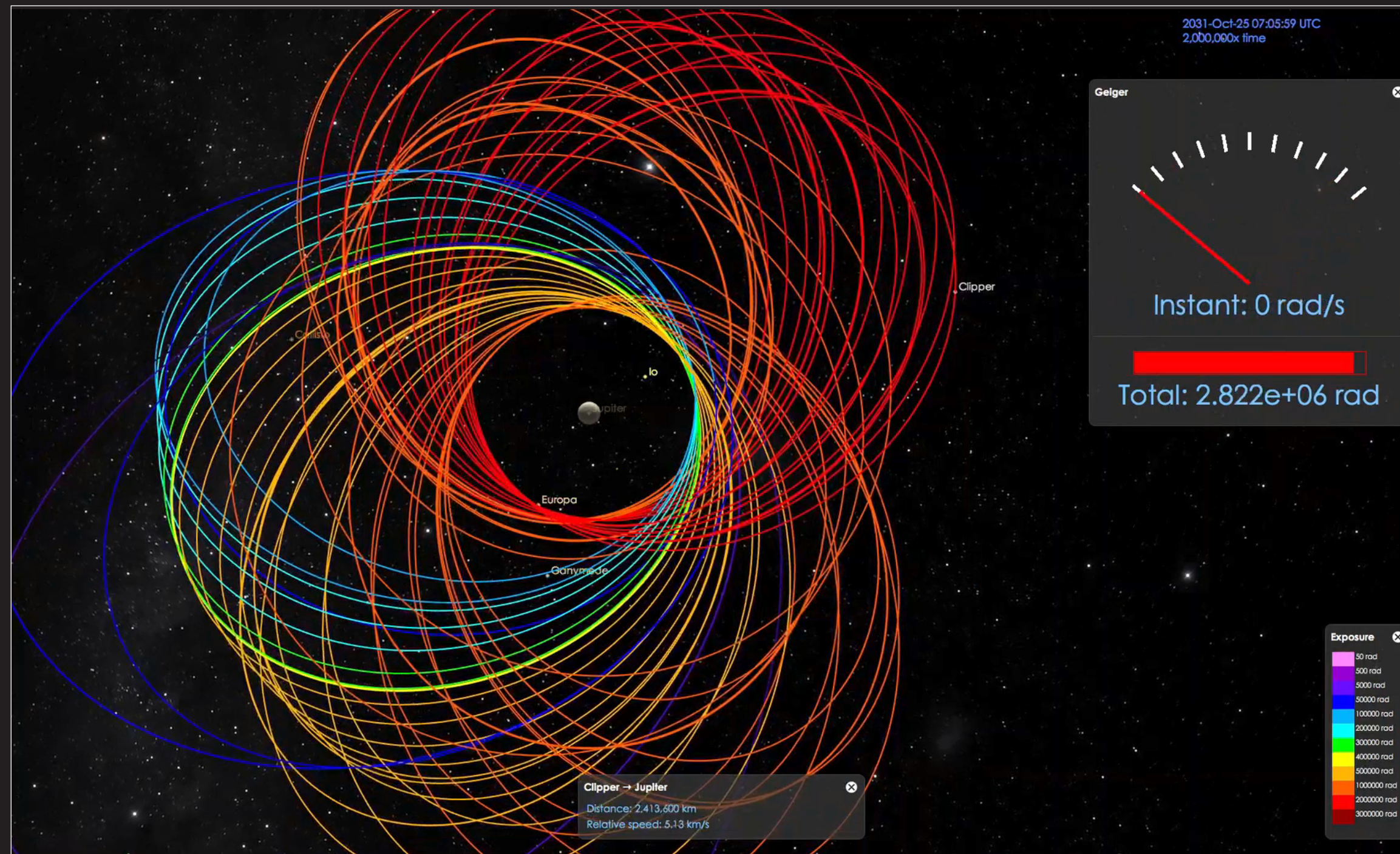


# Jupiter's Radiation Belts





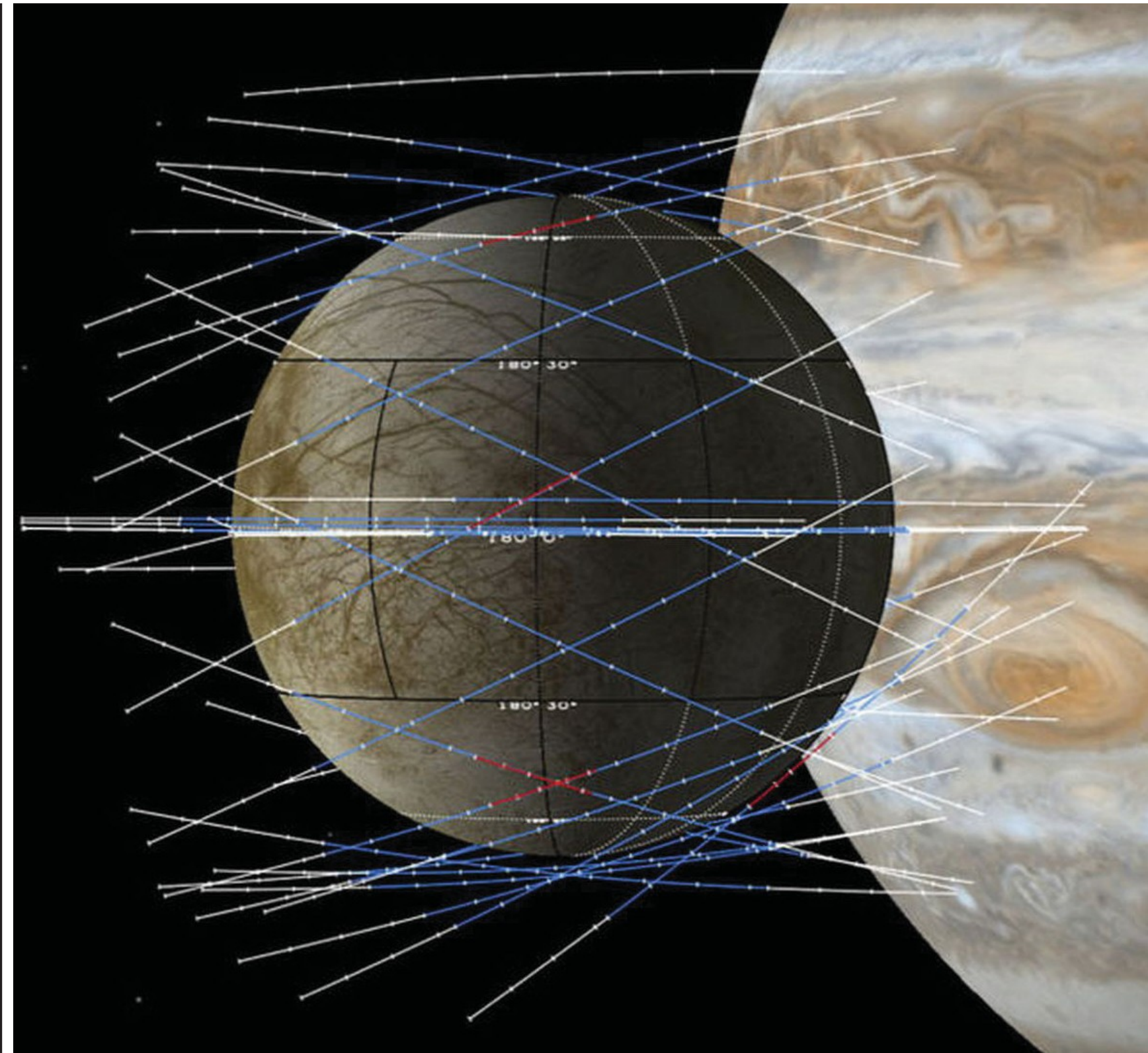
# Spacecraft Radiation Dosage





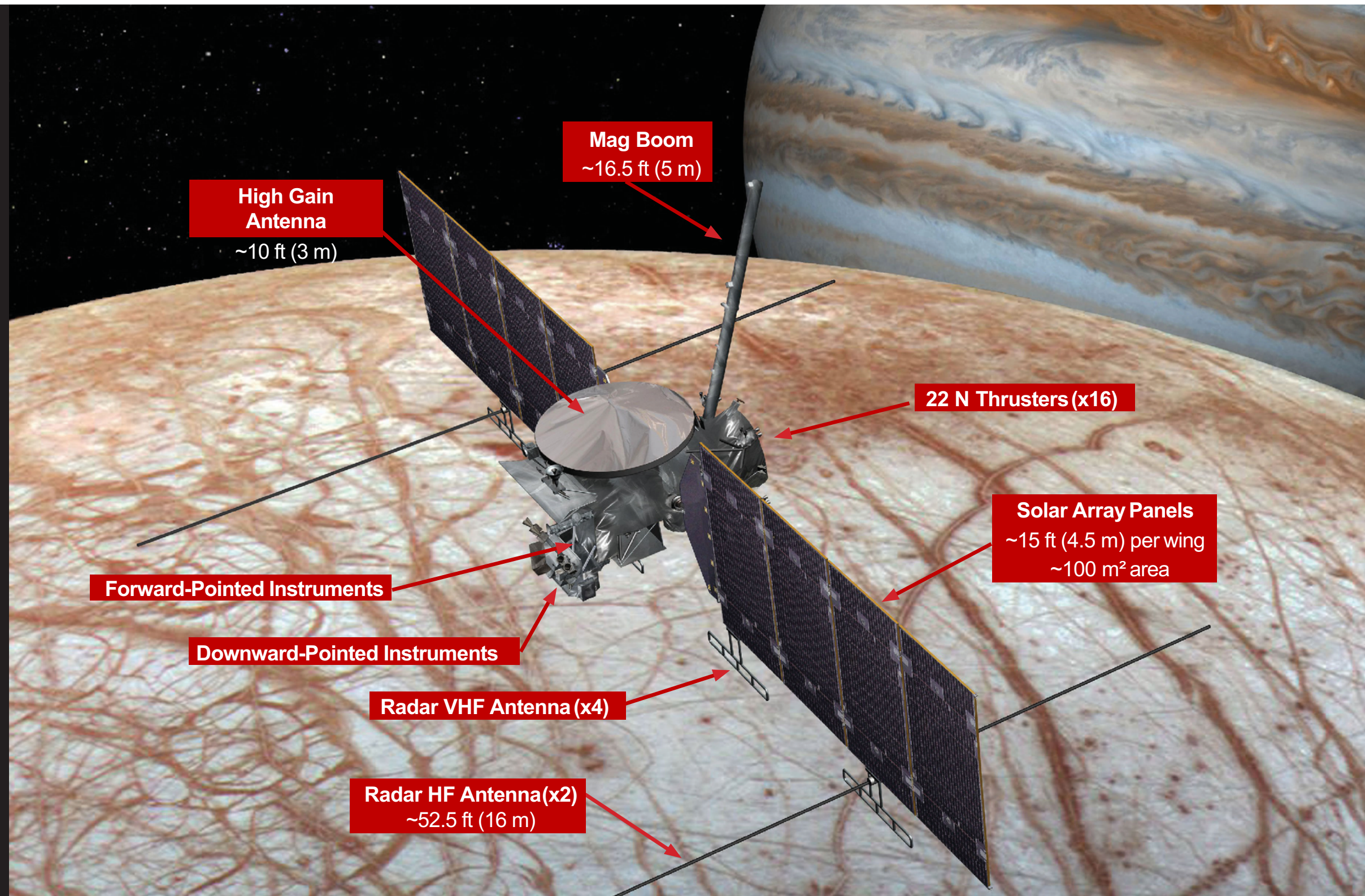
# A Global Web of Fly-bys

- Multiple satellite gravity assists enables “global-regional coverage” of Europa from orbit around Jupiter
- Current mission design consists of 42 low-altitude Europa flybys over 3.5 years
- Minimizes time in high radiation environment
- Simple repetitive operations



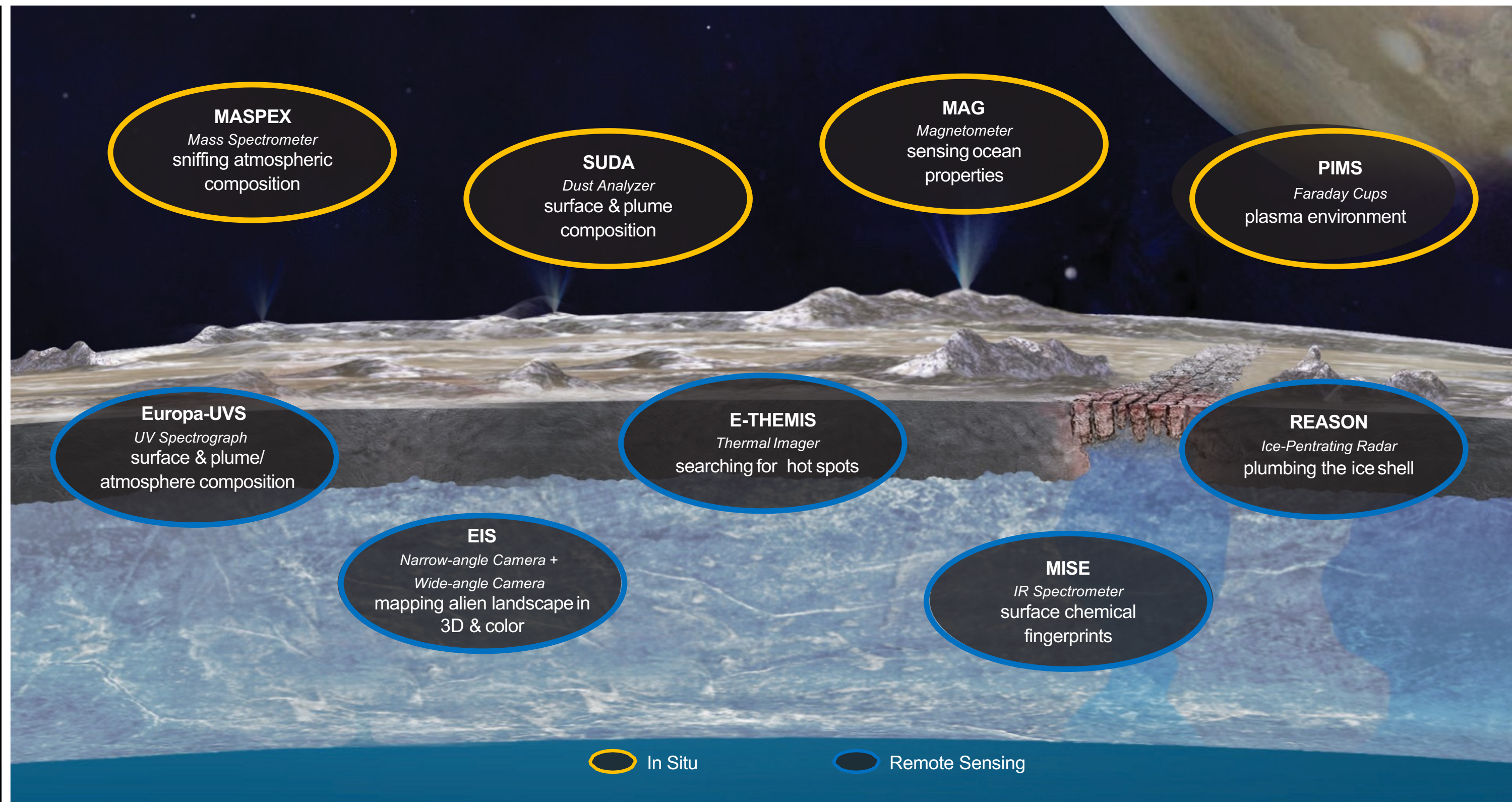


# Europa Clipper Spacecraft



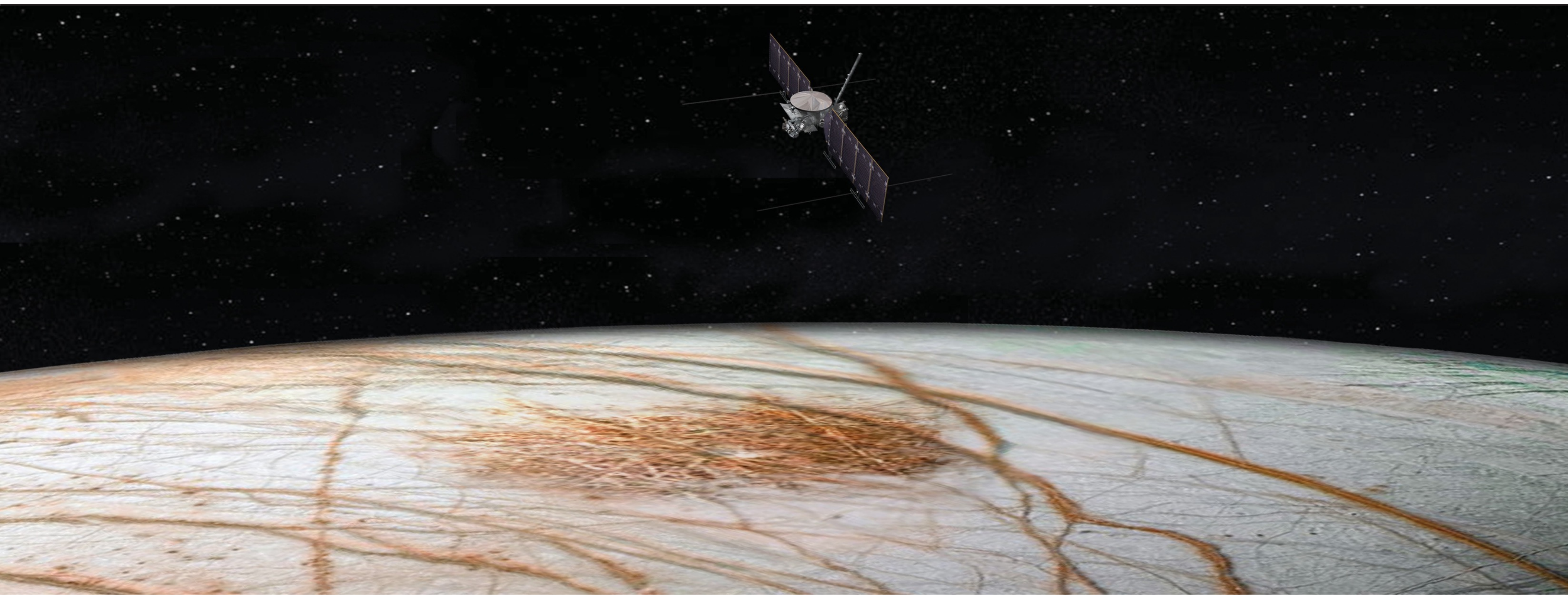


# Europa Clipper Instruments



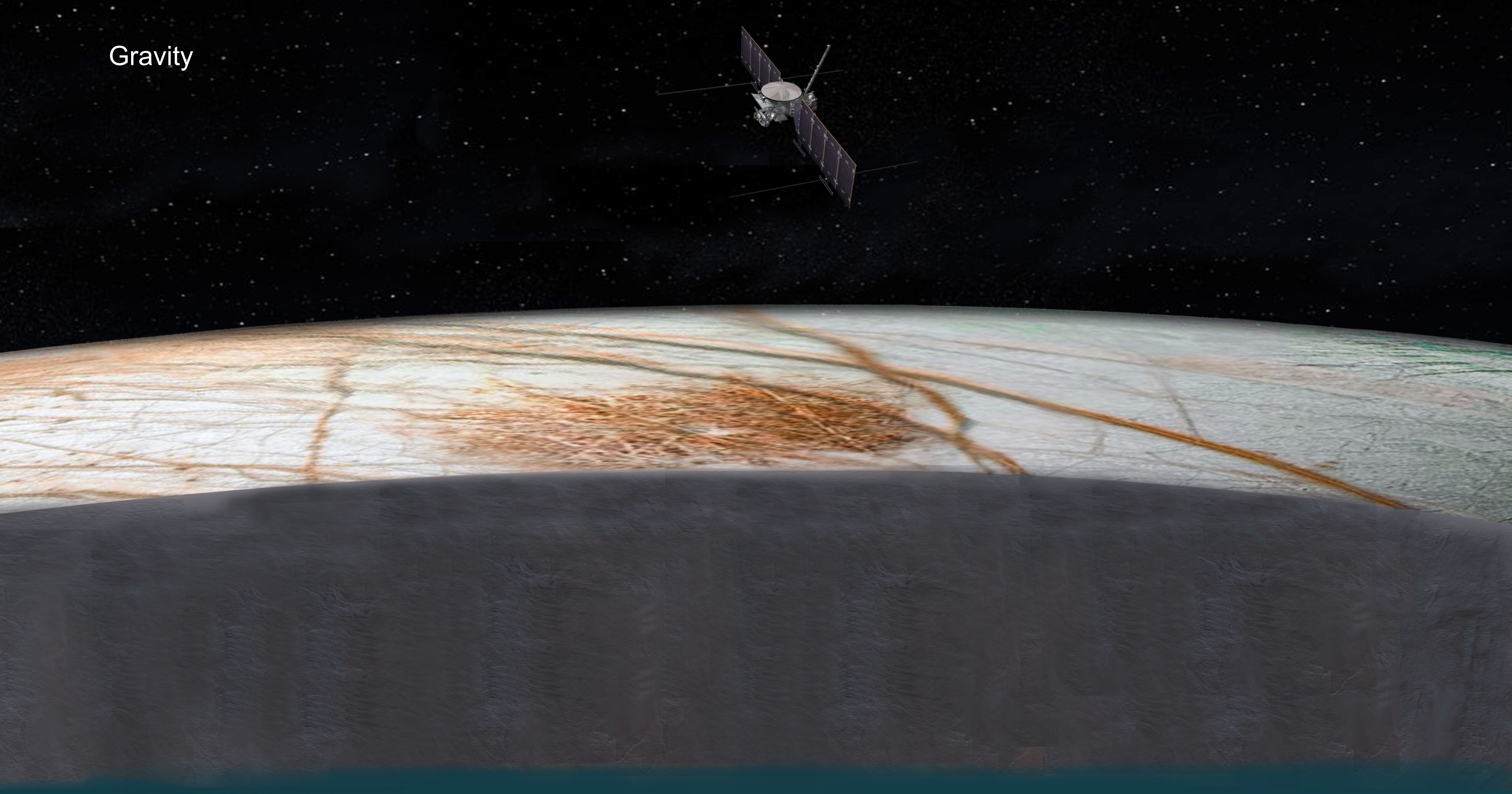


# Europa Clipper Synergistic Science



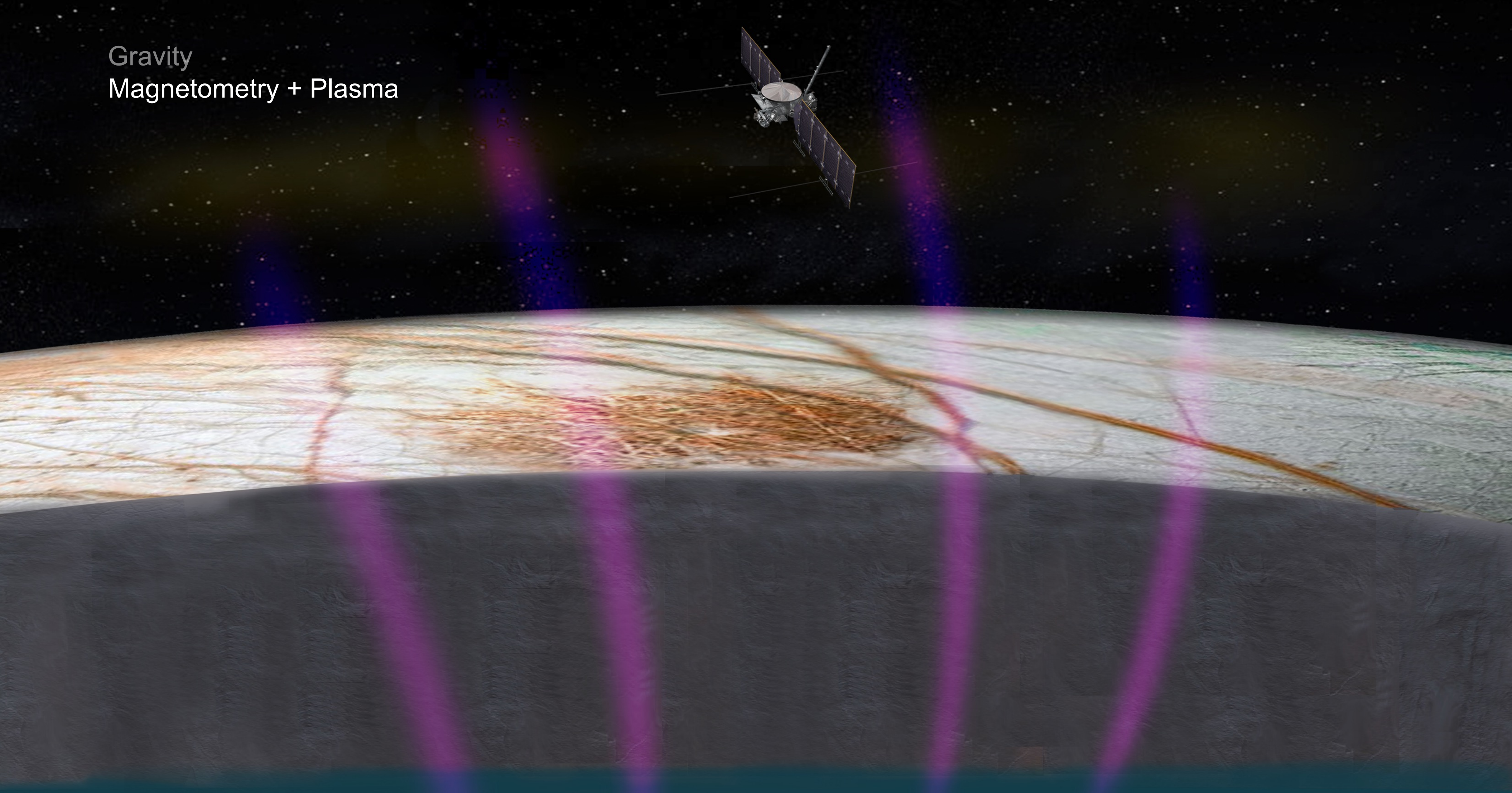


# Gravity



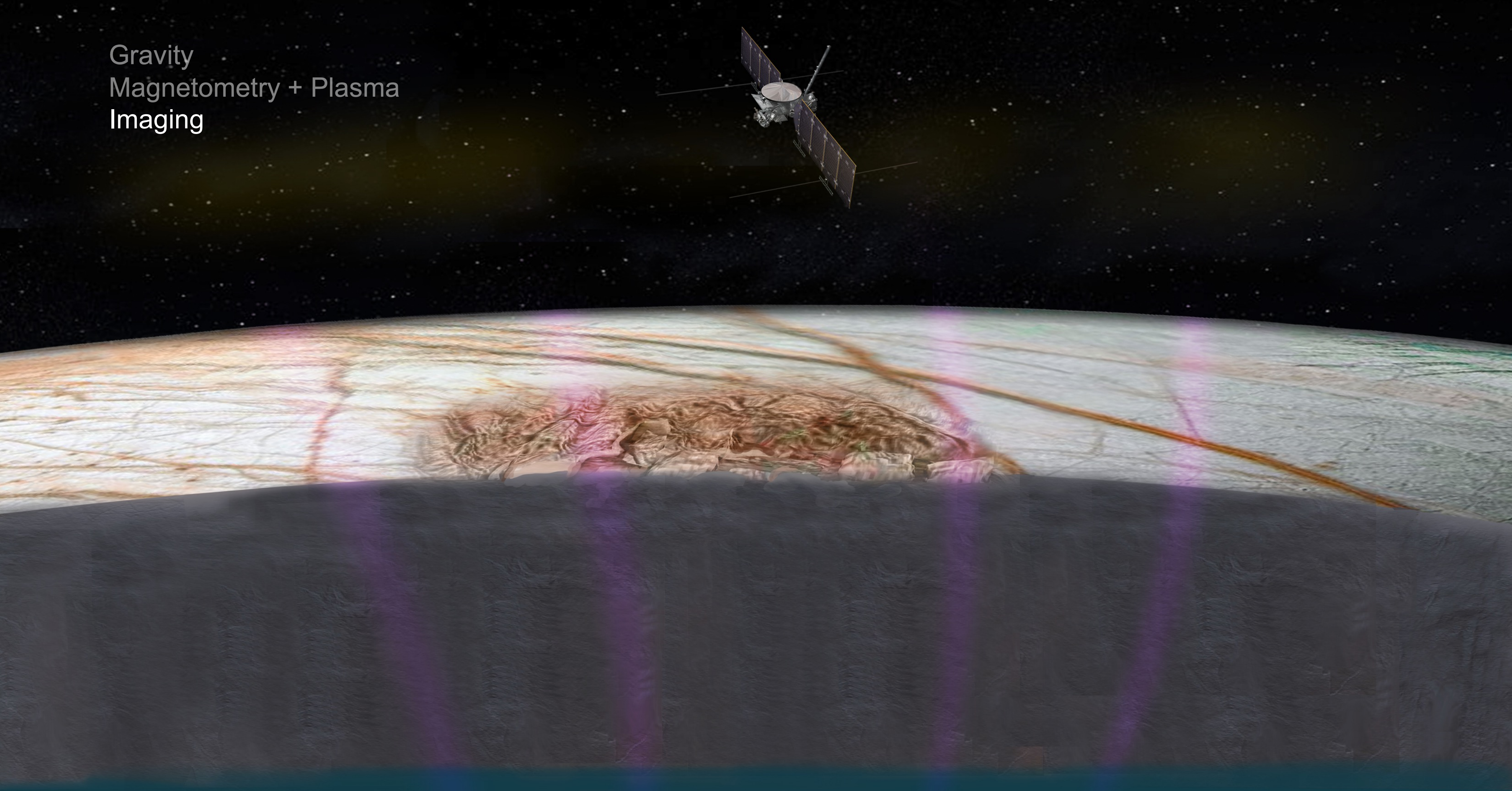


Gravity  
Magnetometry + Plasma





Gravity  
Magnetometry + Plasma  
Imaging





Gravity  
Magnetometry + Plasma  
Imaging  
Infrared



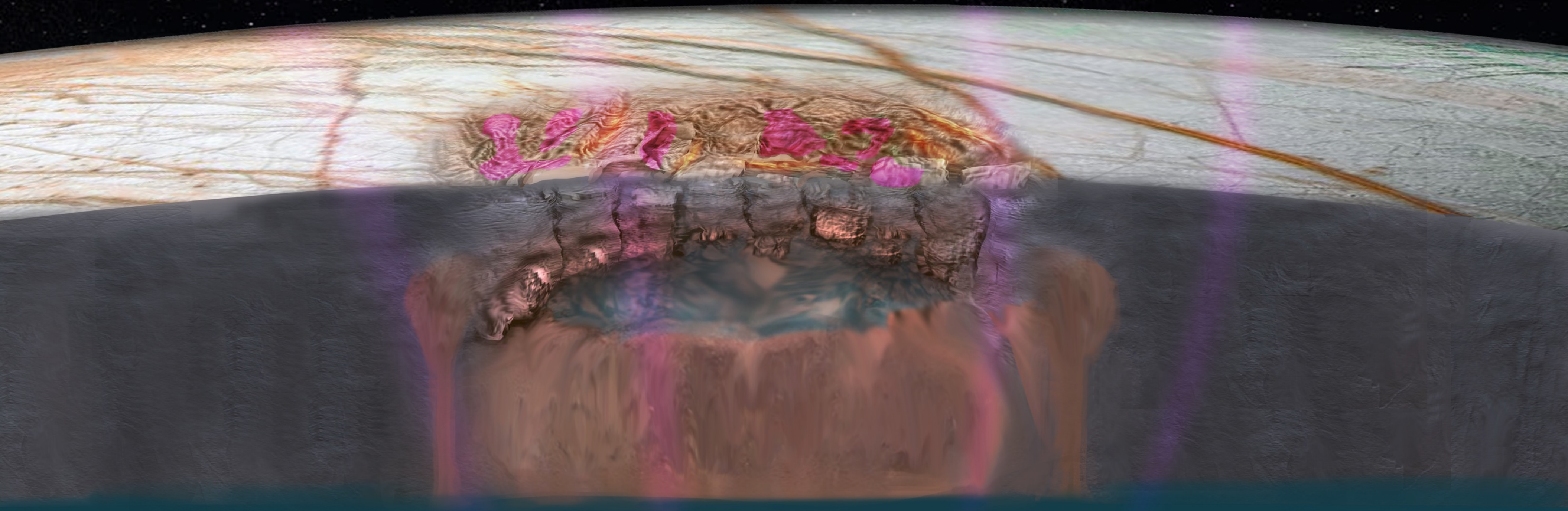


Gravity  
Magnetometry + Plasma  
Imaging  
Infrared  
Thermal



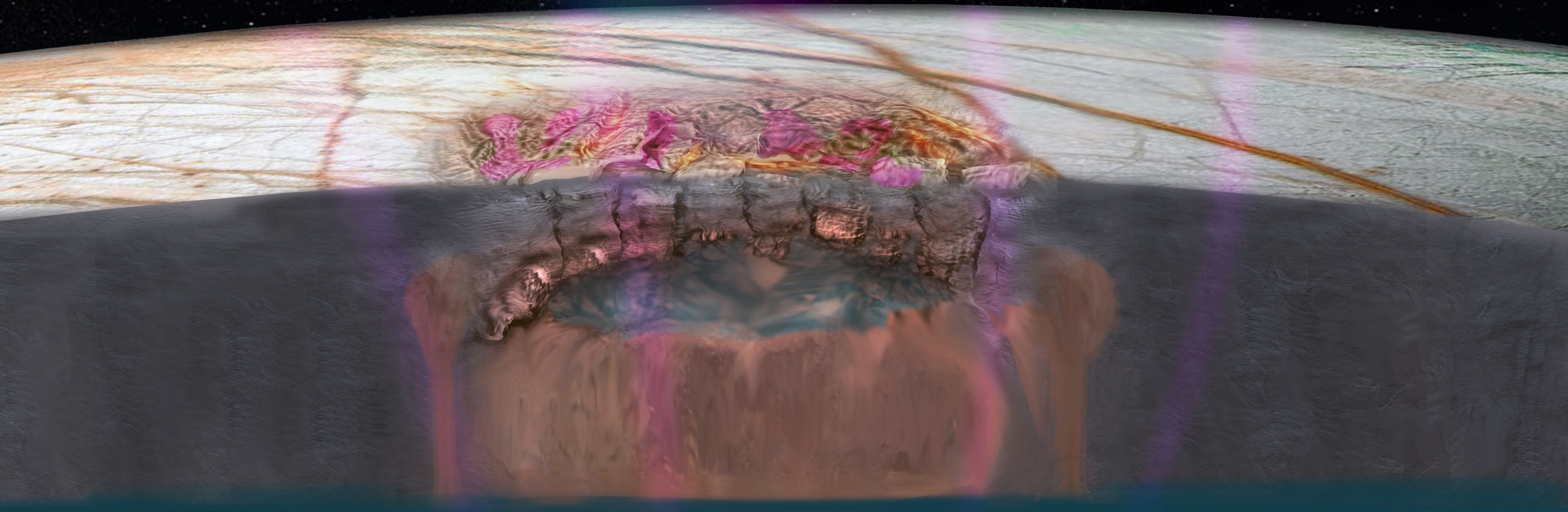


Gravity  
Magnetometry + Plasma  
Imaging  
Infrared  
Thermal  
Radar



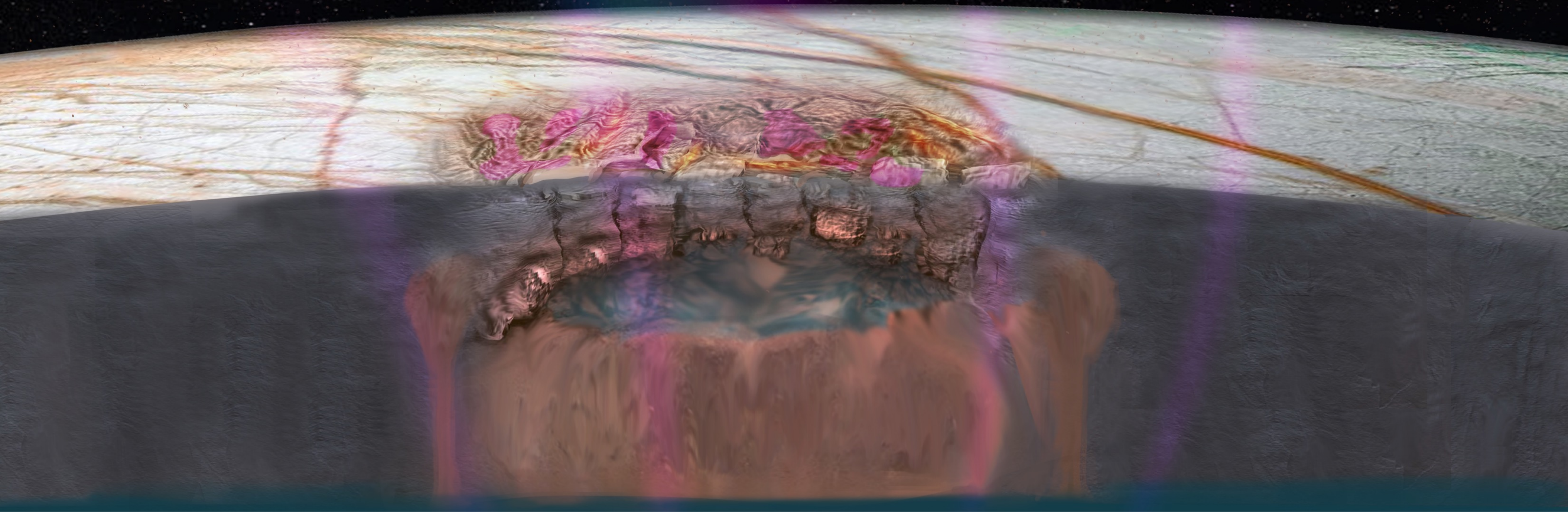


Gravity  
Magnetometry + Plasma  
Imaging  
Infrared  
Thermal  
Radar  
Ultraviolet



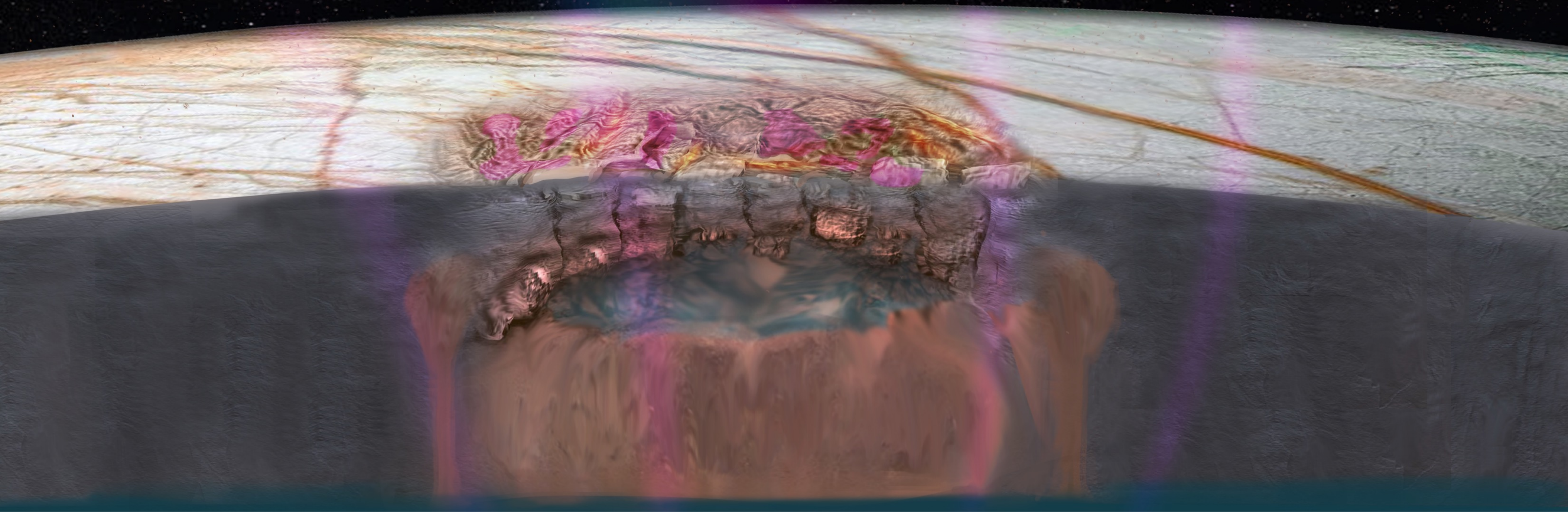


Gravity  
Magnetometry + Plasma  
Imaging  
Infrared  
Thermal  
Radar  
Ultraviolet  
Gas + Dust Mass Spectroscopy



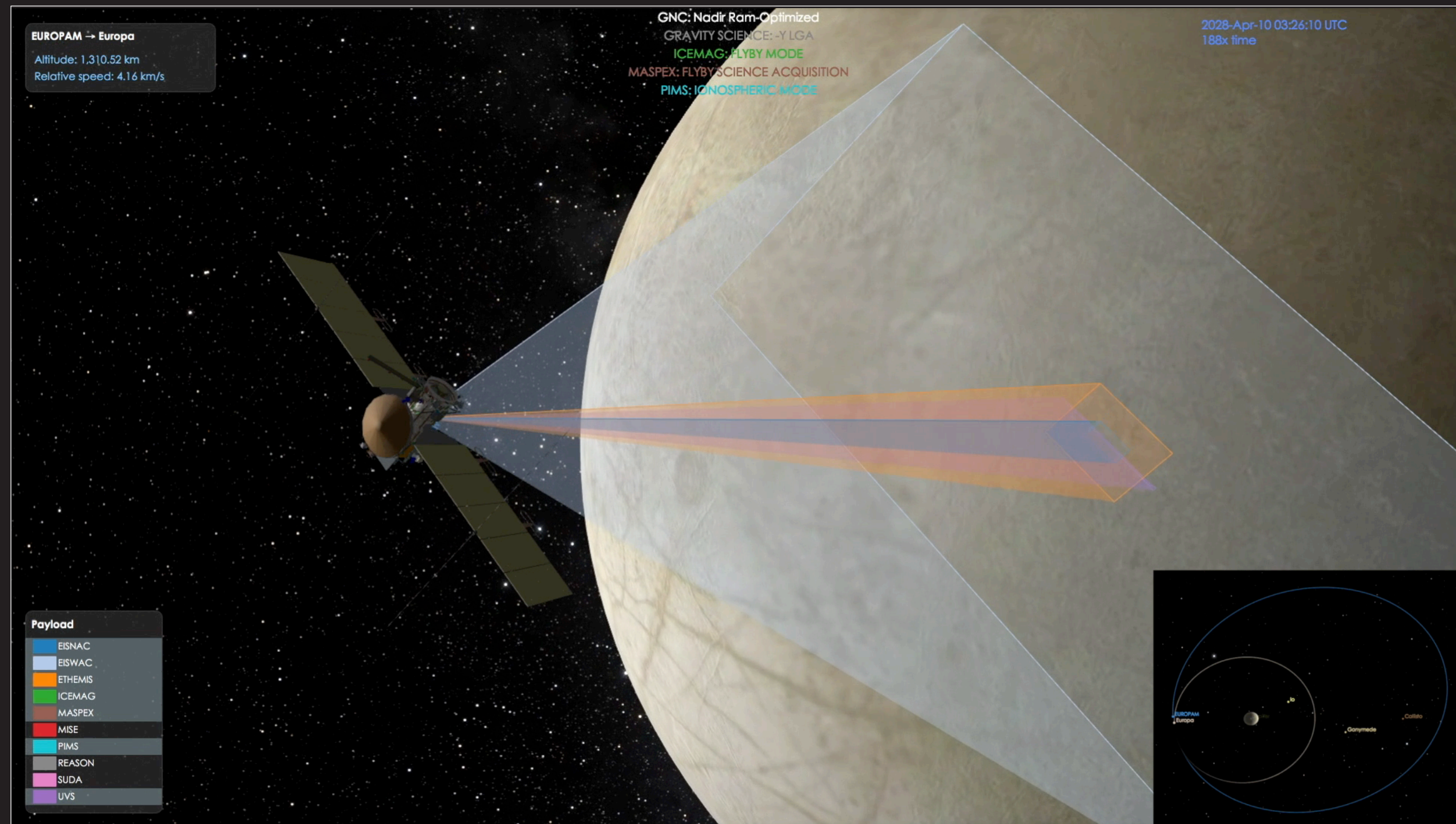


Gravity  
Magnetometry + Plasma  
Imaging  
Infrared  
Thermal  
Radar  
Ultraviolet  
Gas + Dust Mass Spectroscopy





# Europa Clipper Flyby Animation

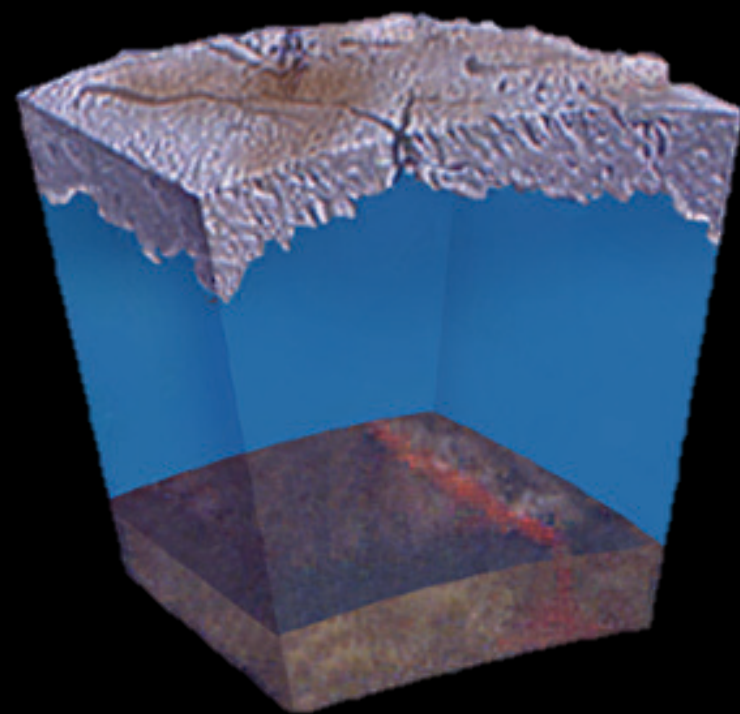




# Europa Clipper Mission Science

Goal: Explore Europa to investigate its habitability

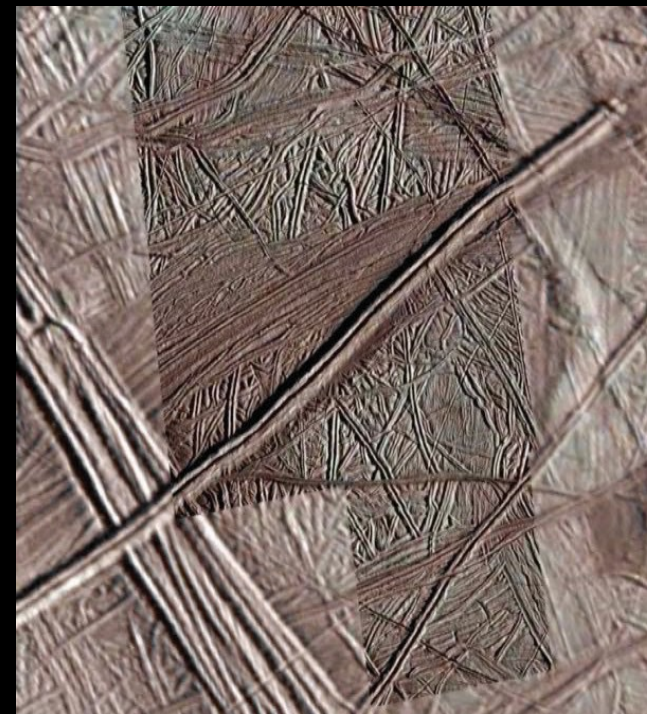
## Ice Shell and Ocean



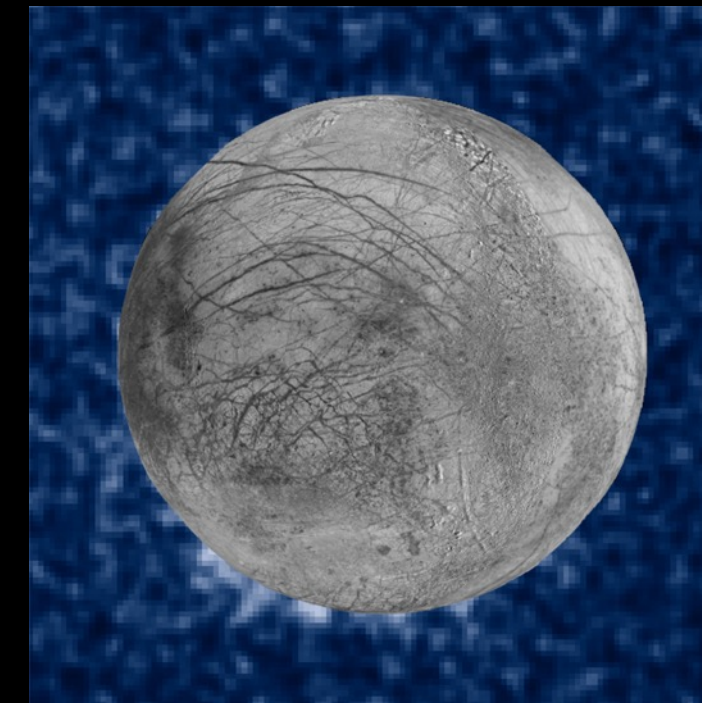
## Composition



## Geology

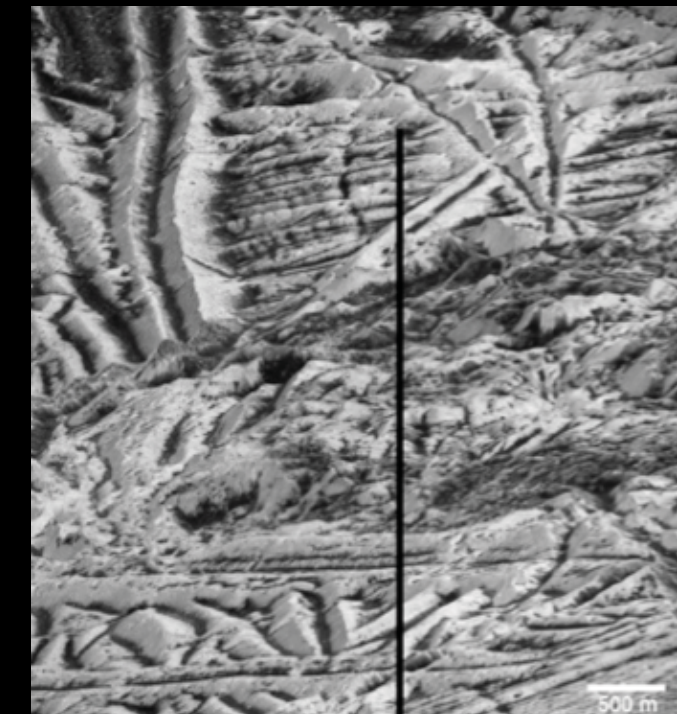


## Activity



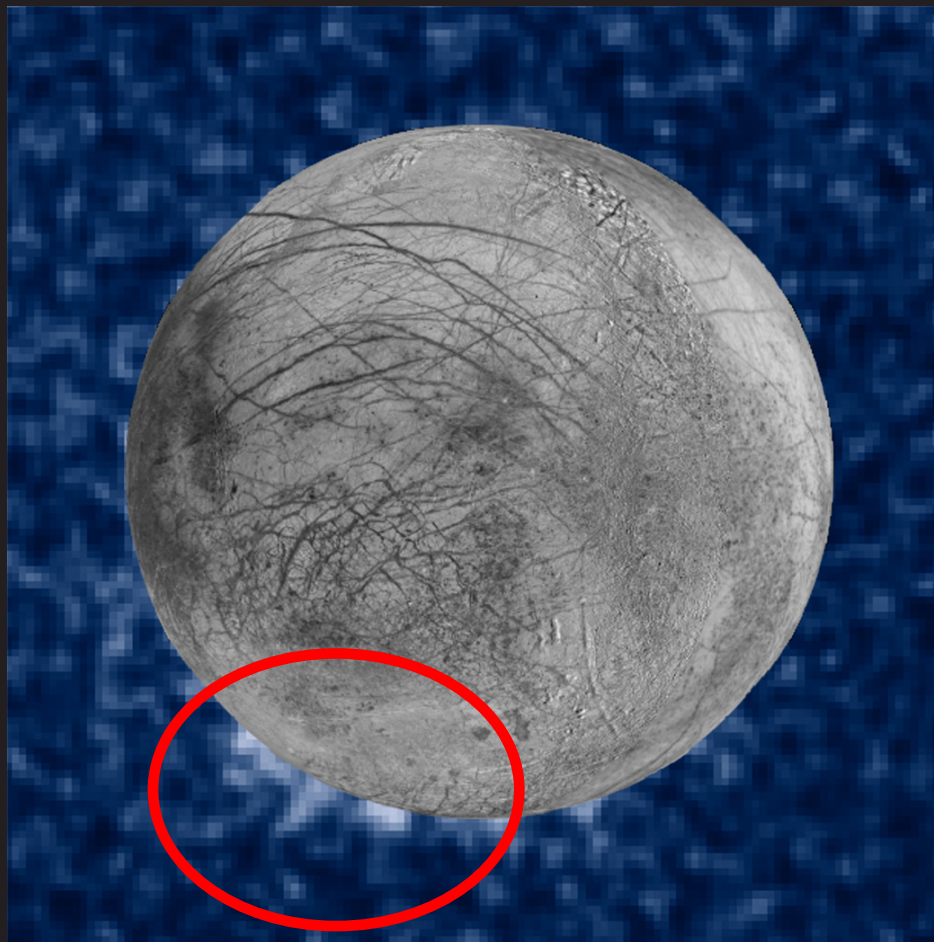
Credits: NASA/ESA W. Sparks  
(STScI)/USGS Astrogeology Science  
Center

## Reconnaissance





# Plumes?



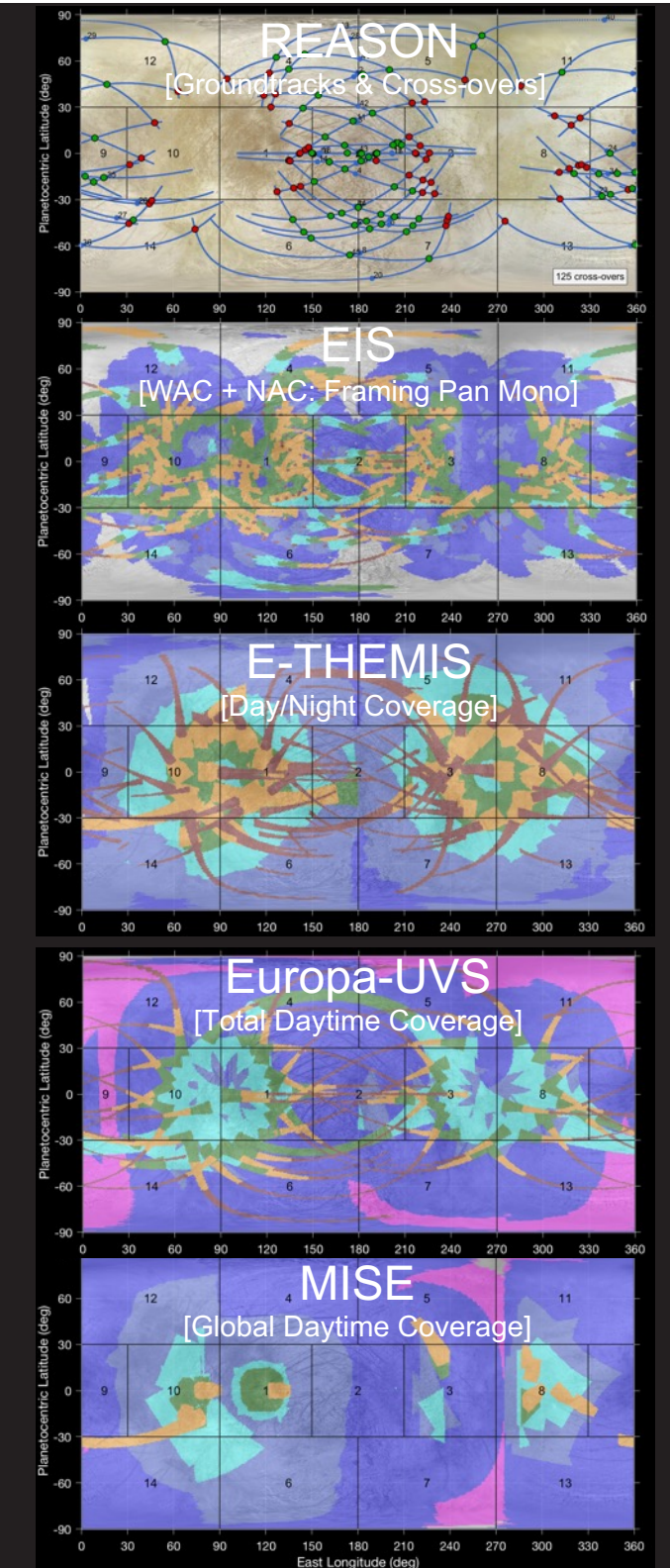
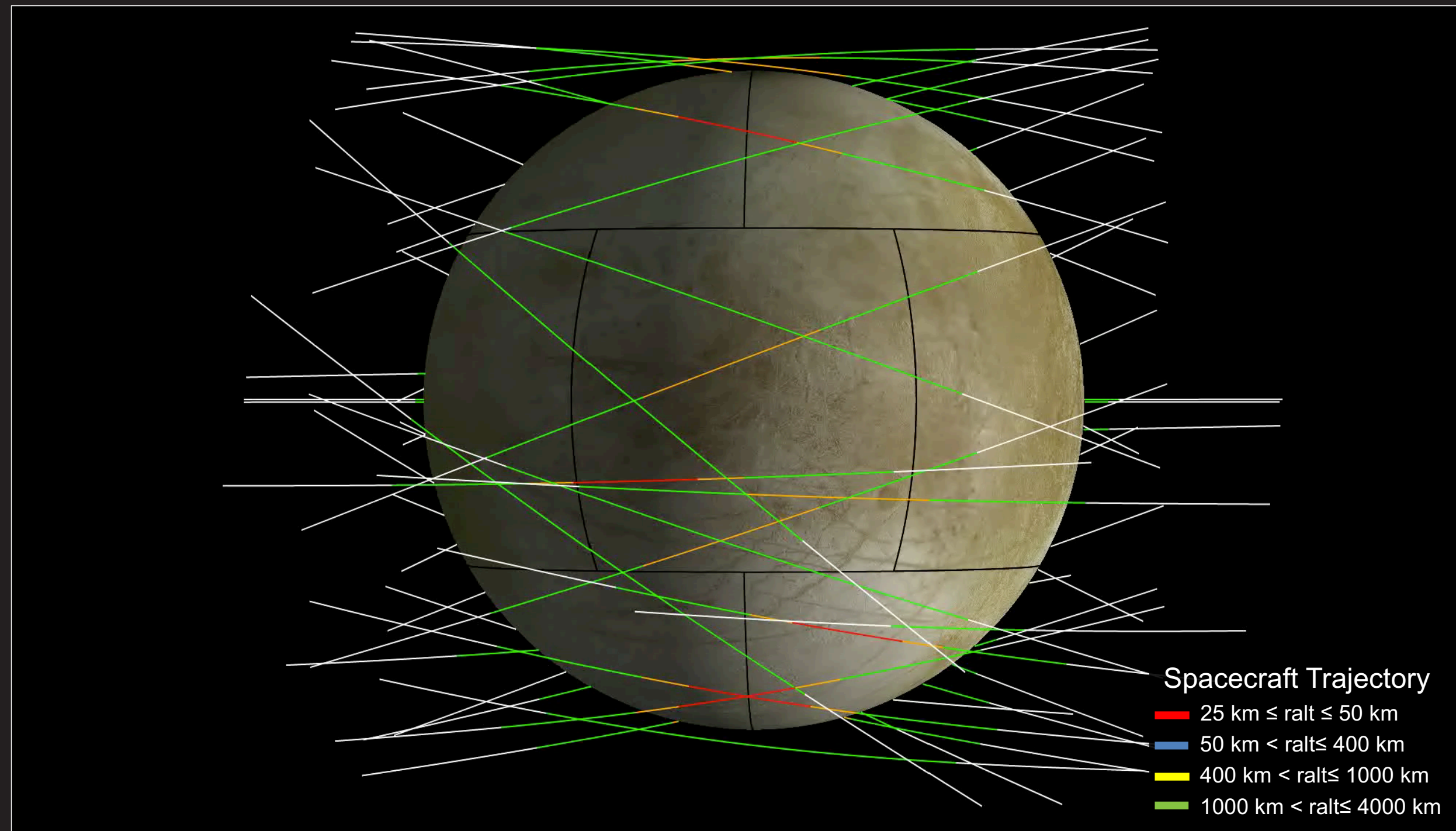
Composition image  
from Hubble Space  
Telescope' Imaging  
Spectrograph,  
taken in Jan 2014.



Artist's conception

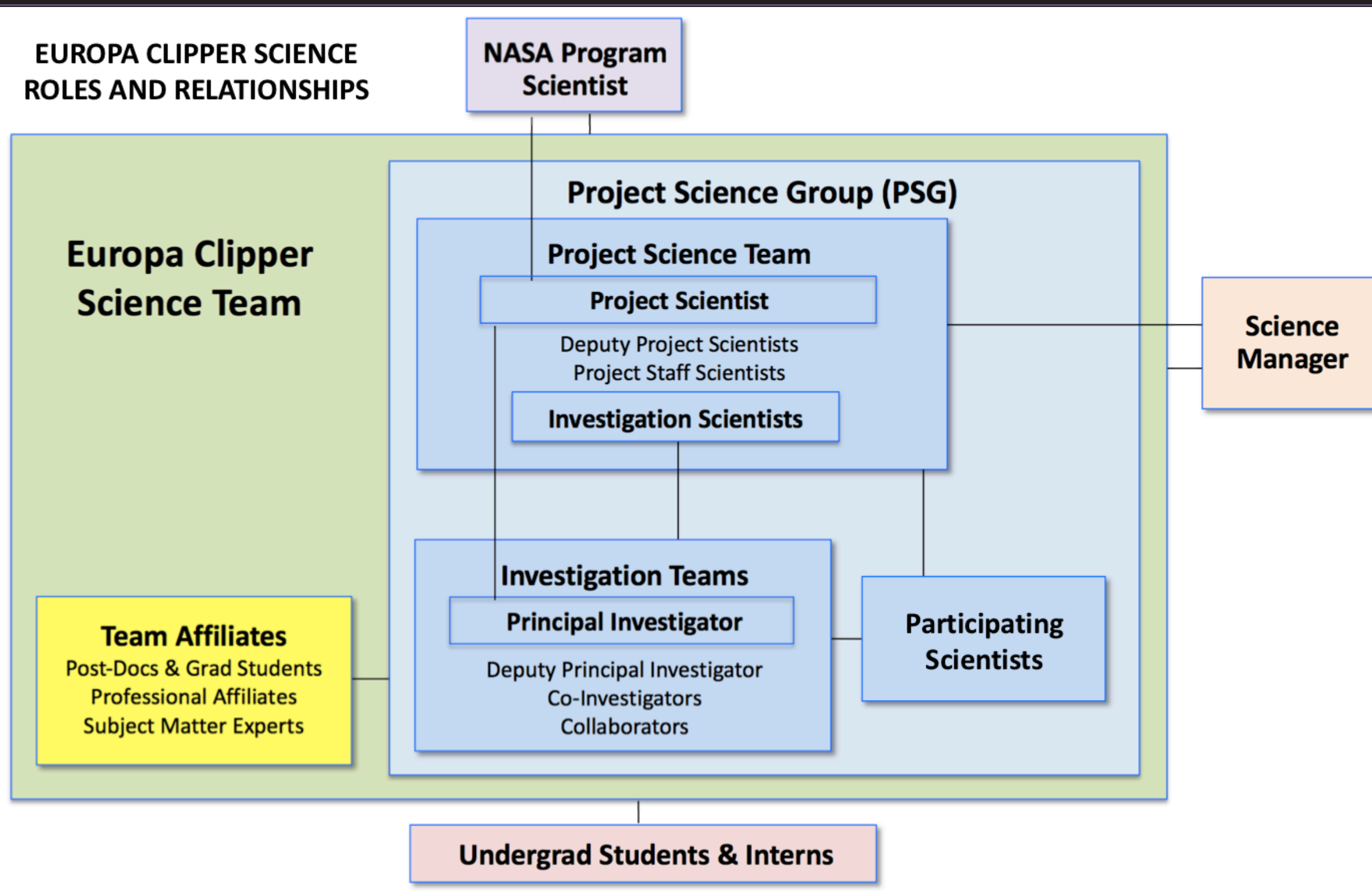


# Innovative Mission Concept Coverage in Potential Plume Region





# Europa Clipper Science Team: One Team



The Europa Clipper Science Team operates as a single entity. All team members have:

- opportunity to participate in science strategic planning efforts of the Thematic Working Groups
- the Project Science Group (PSG) meetings, as well as other cross-investigation meetings.
- Access to data products and the process for participation in publications of team members is codified in a standard set of Rules of the Road.

**As is often true in science, it is at the overlapping boundaries of our sub-fields that the greatest insights and discoveries will be made.**

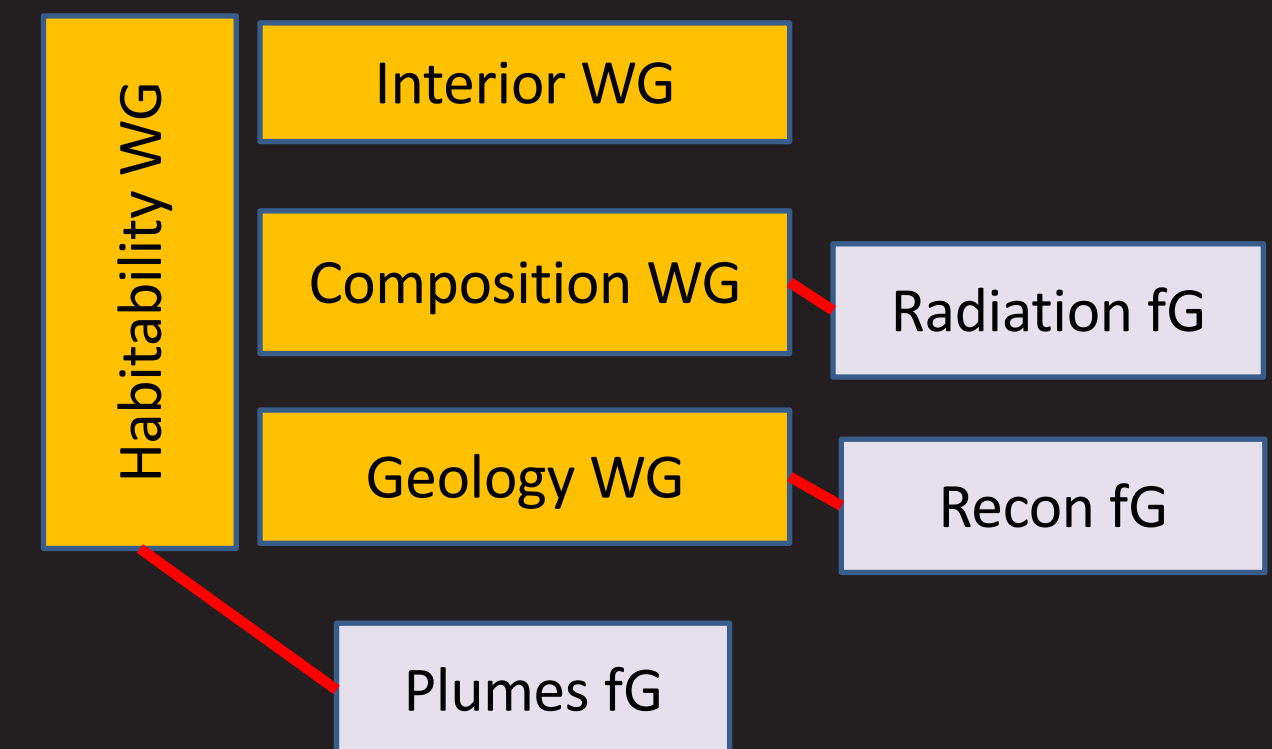


# Europa Clipper Science Team Structure

Europa Clipper Science Goal: **Explore Europa to investigate its habitability.**

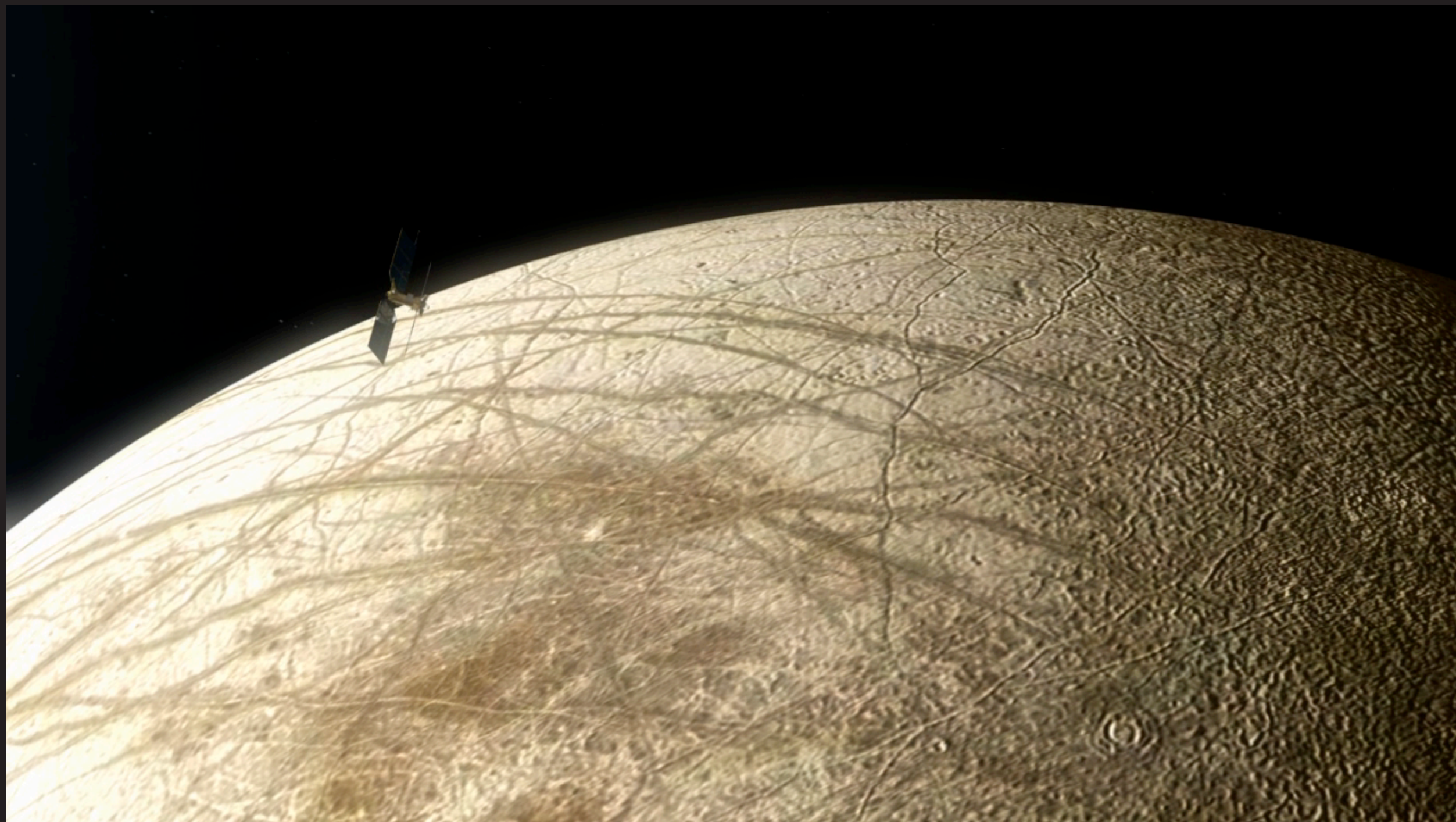
The payload comprises a suite of science instruments that together will support **three key objectives**:

- 1) Ice Shell & Ocean:** Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange
- 2) Composition:** Understand the habitability of Europa's ocean through composition and chemistry
- 3) Geology:** Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities



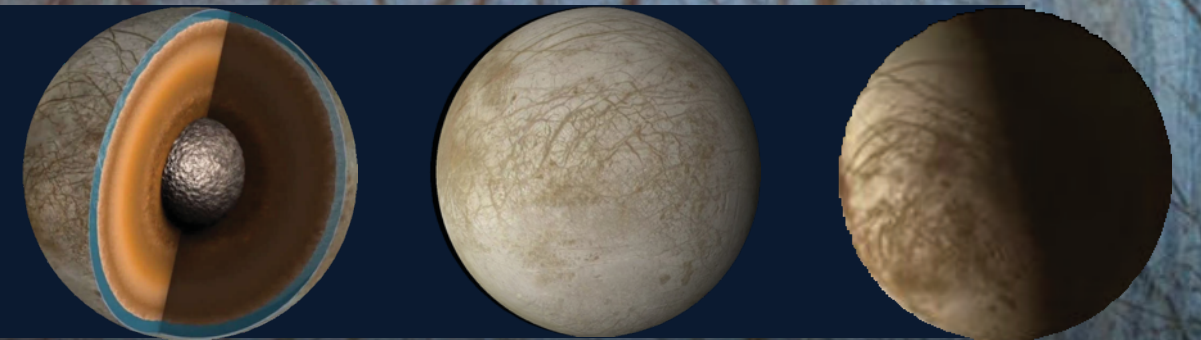
Thematic Working Group and Focus Group Structure. Each TWG and FG is composed of team members from various investigation teams







<https://europa.nasa.gov>

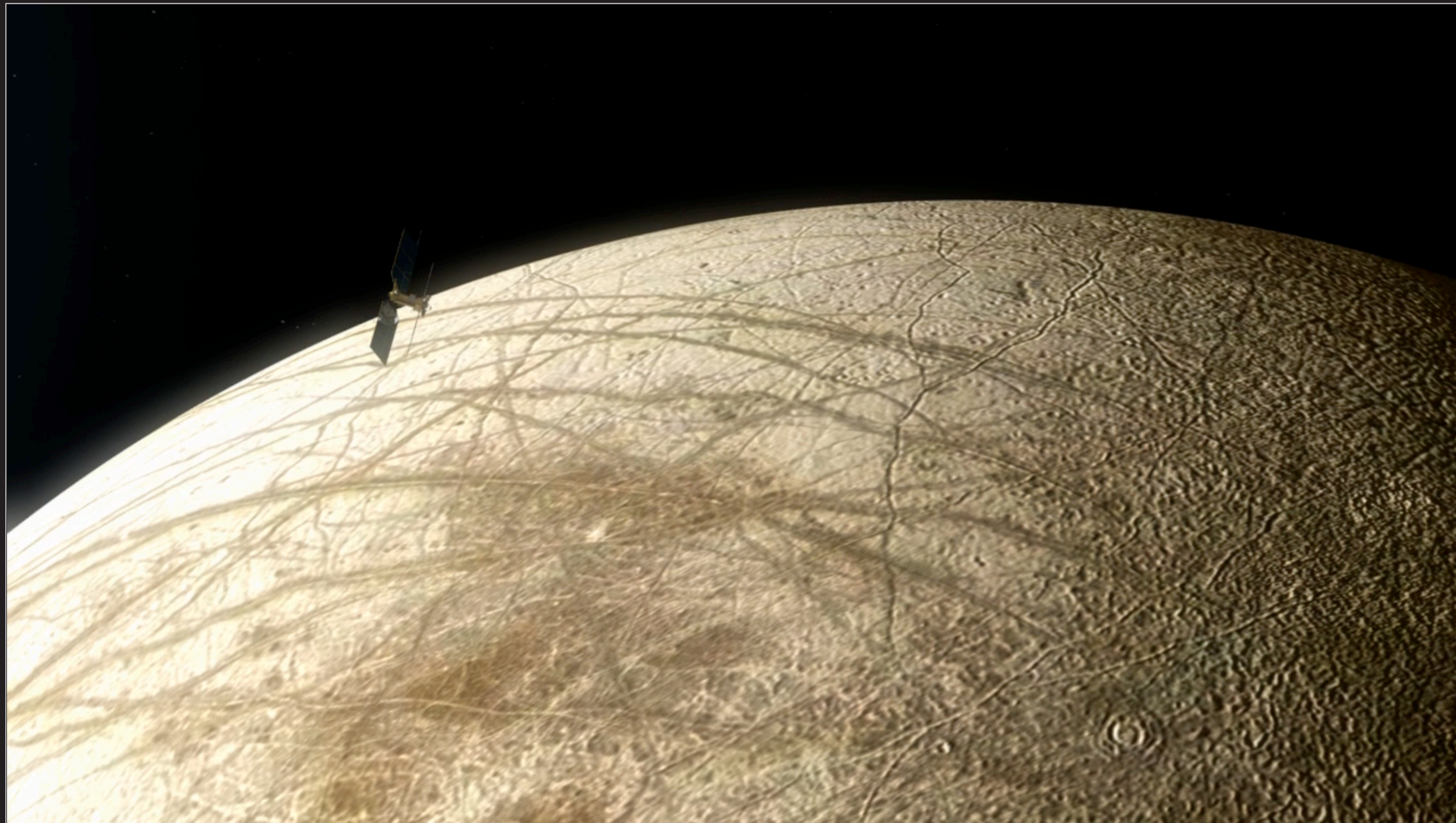




# BACKUP SLIDES

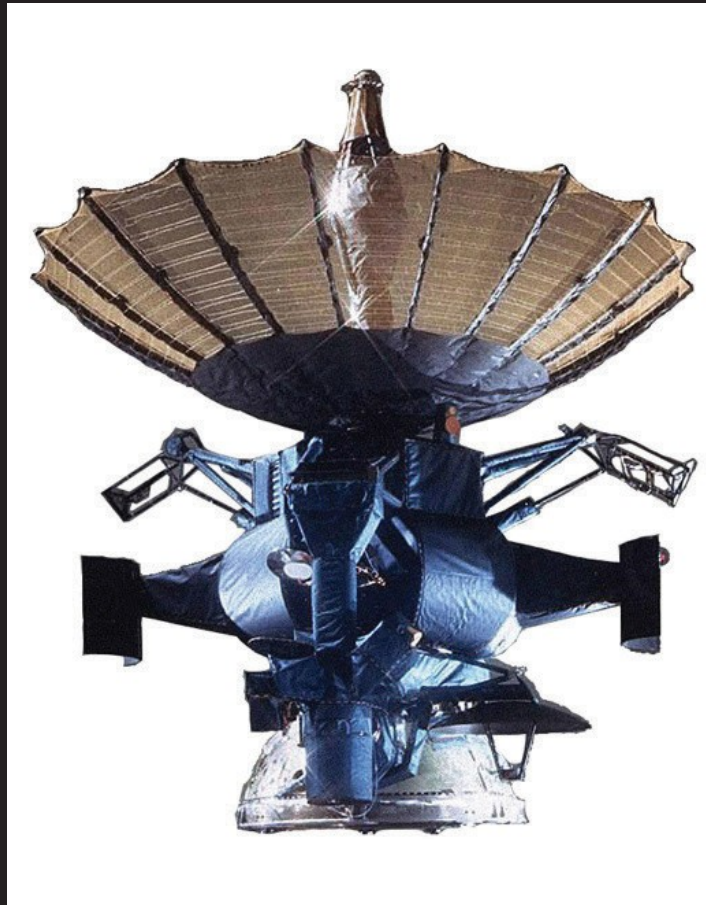


# Plume Fly-Through: Artist's Conception

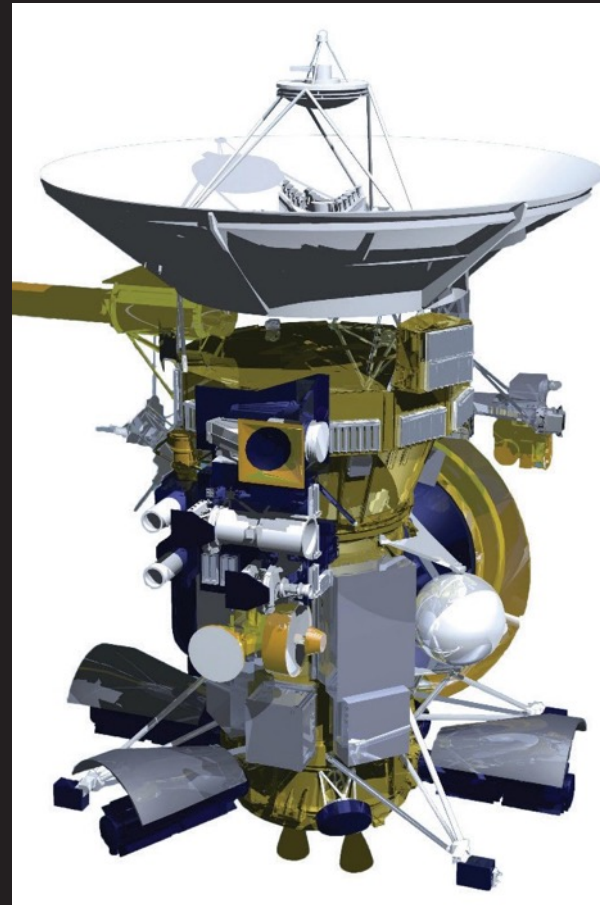




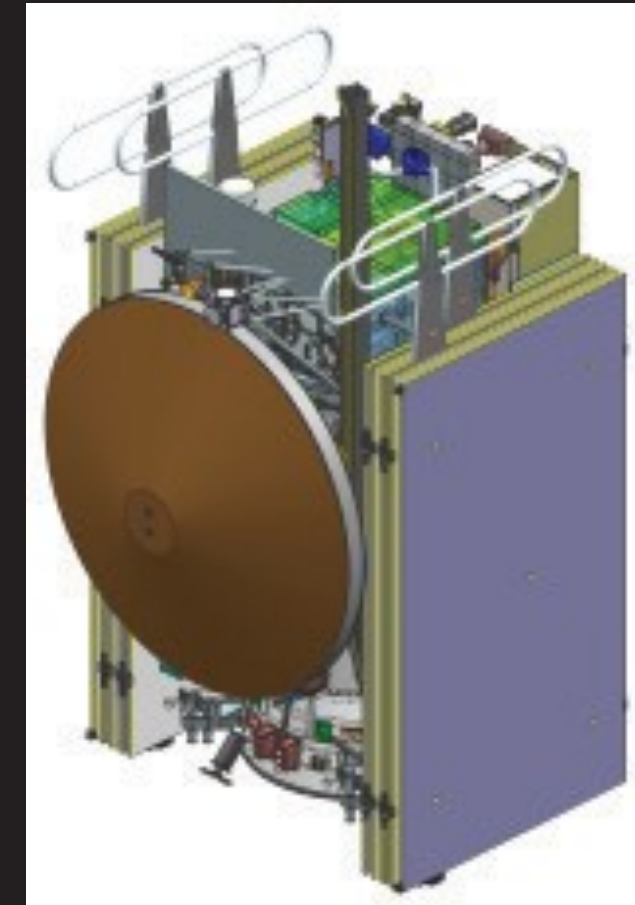
# Outer Planet Spacecraft



Galileo



Cassini

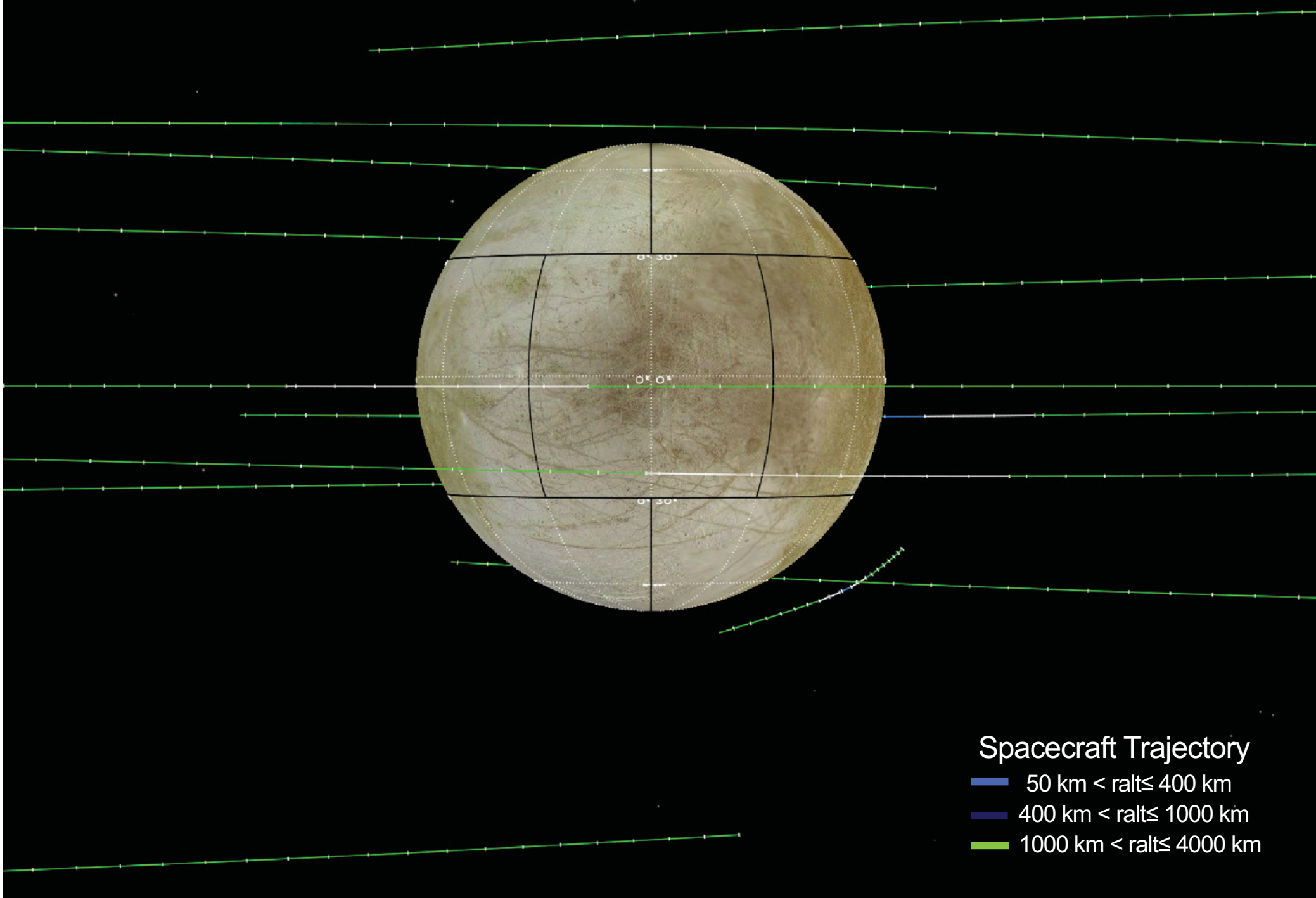


Europa Clipper

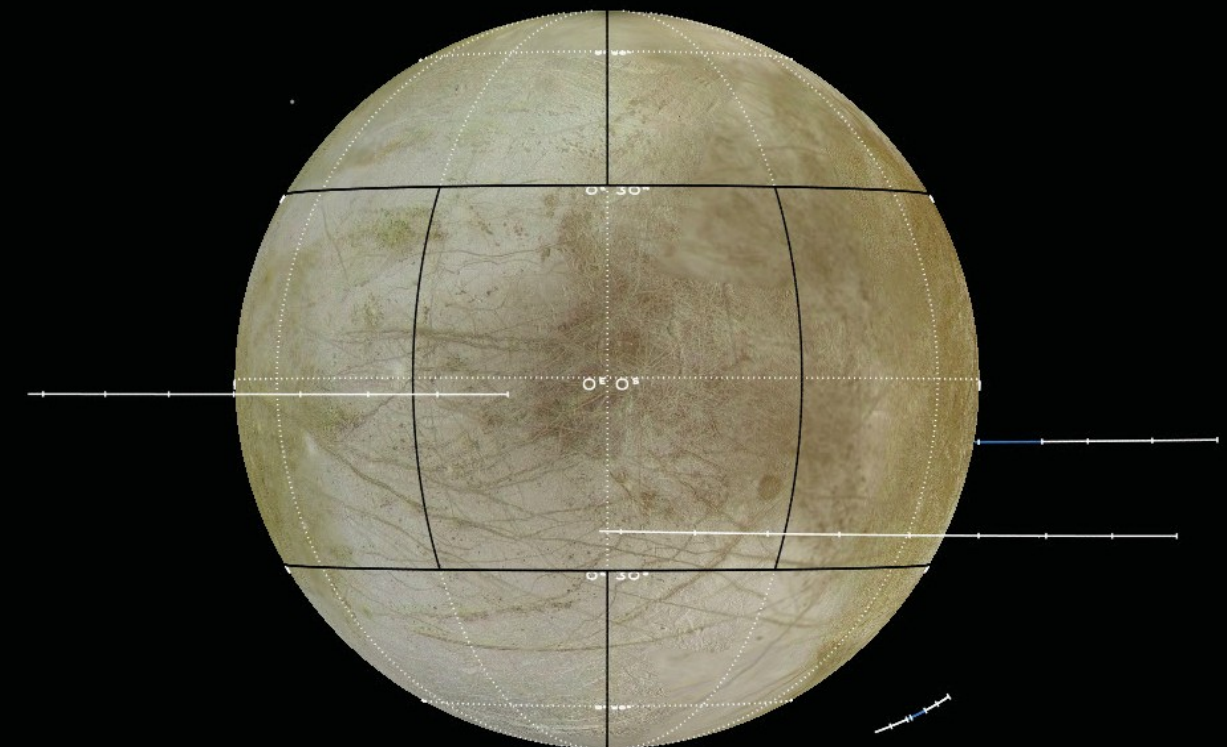


# Galileo Flybys Of Europa

Total of 11 Galileo Flybys of Europa

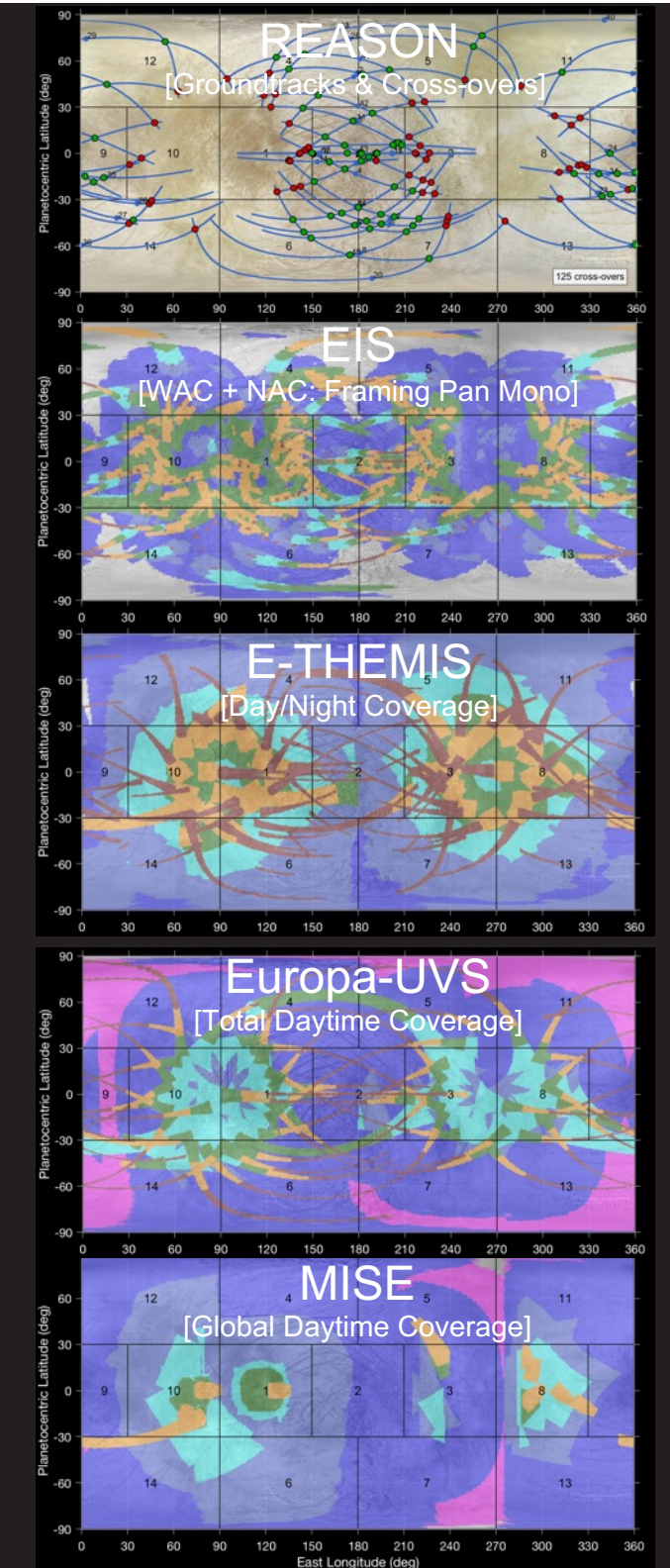
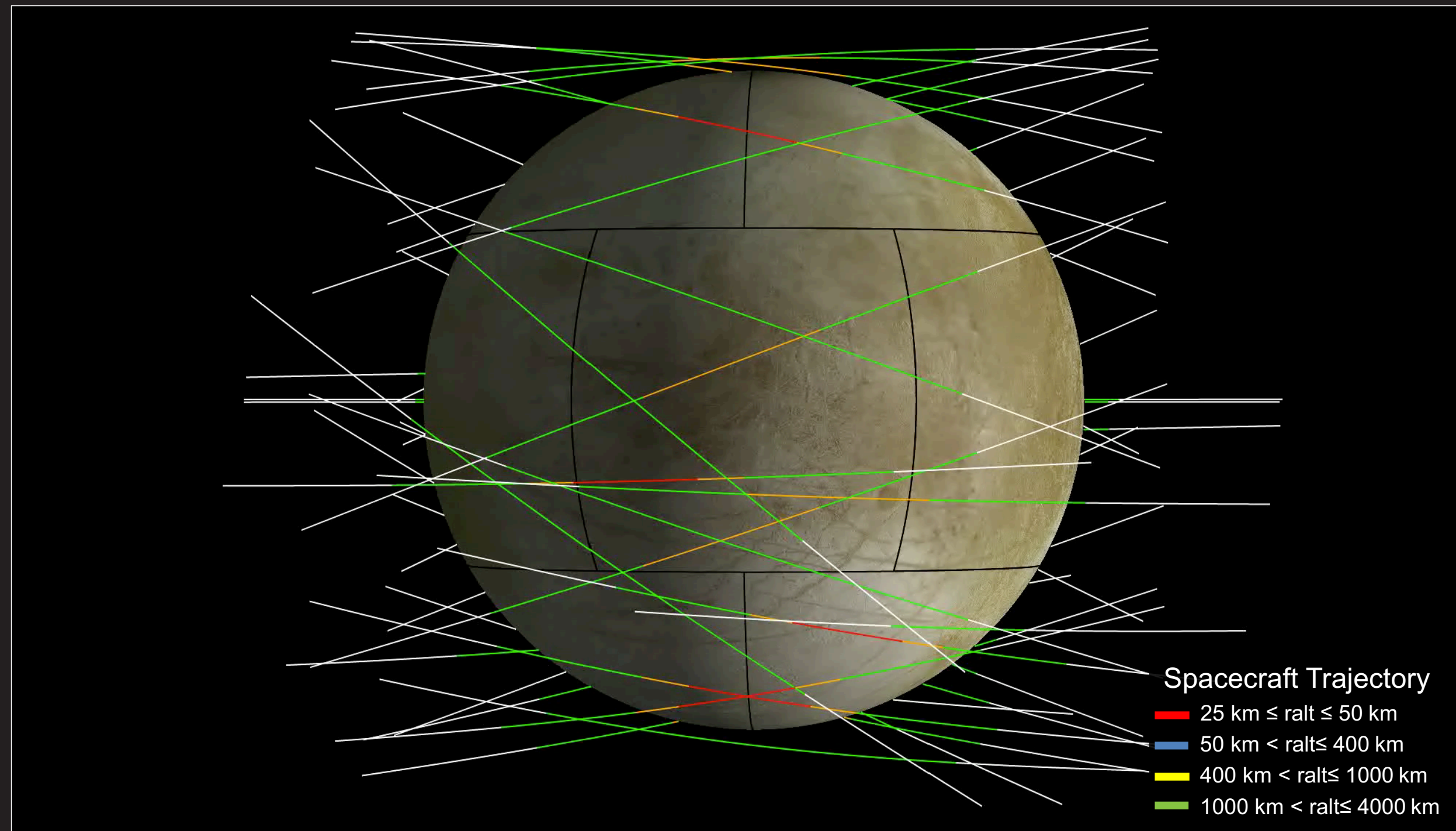


Galileo Flybys Under 1,000 km



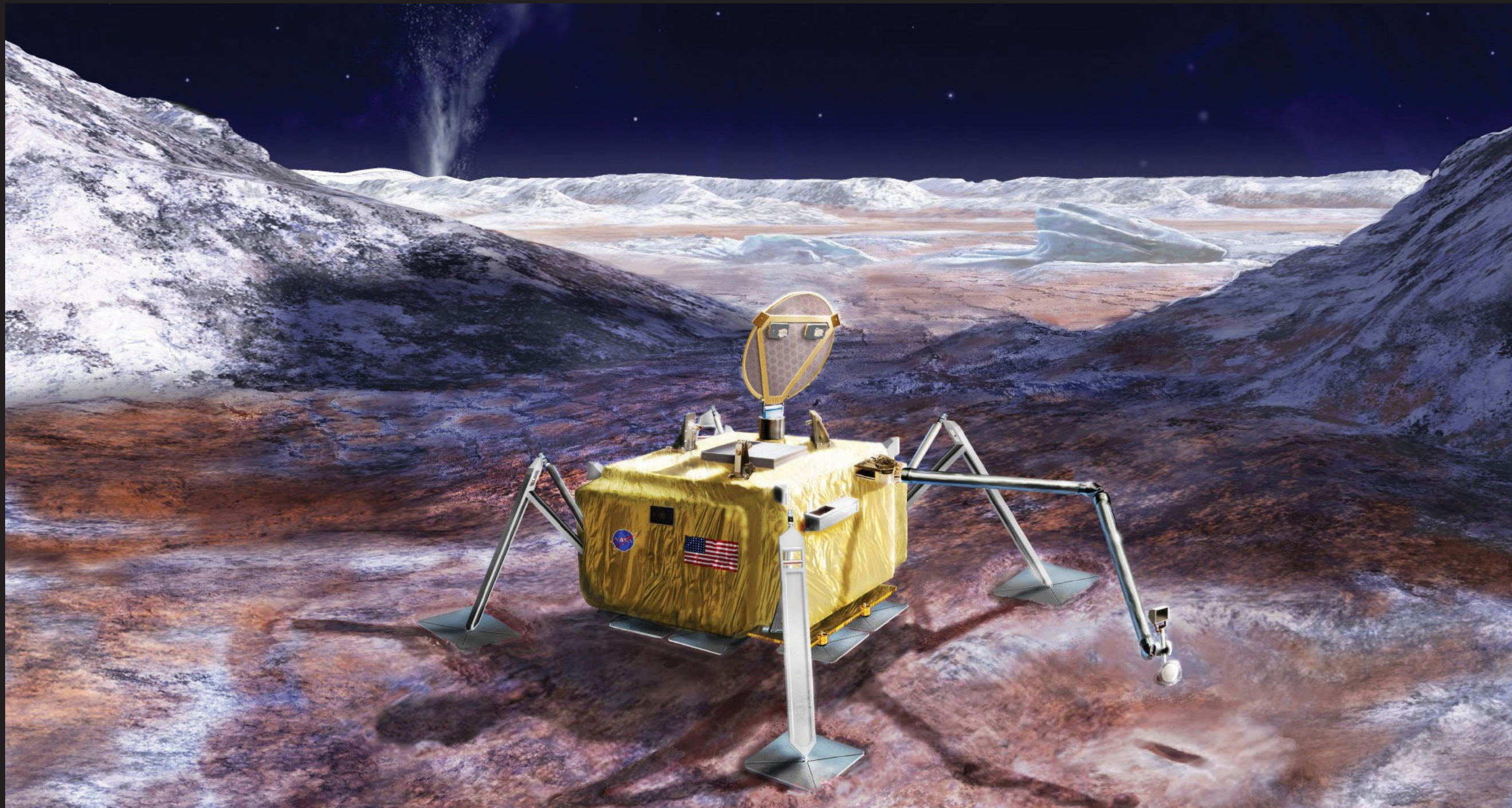


# Innovative Mission Concept Coverage in Potential Plume Region





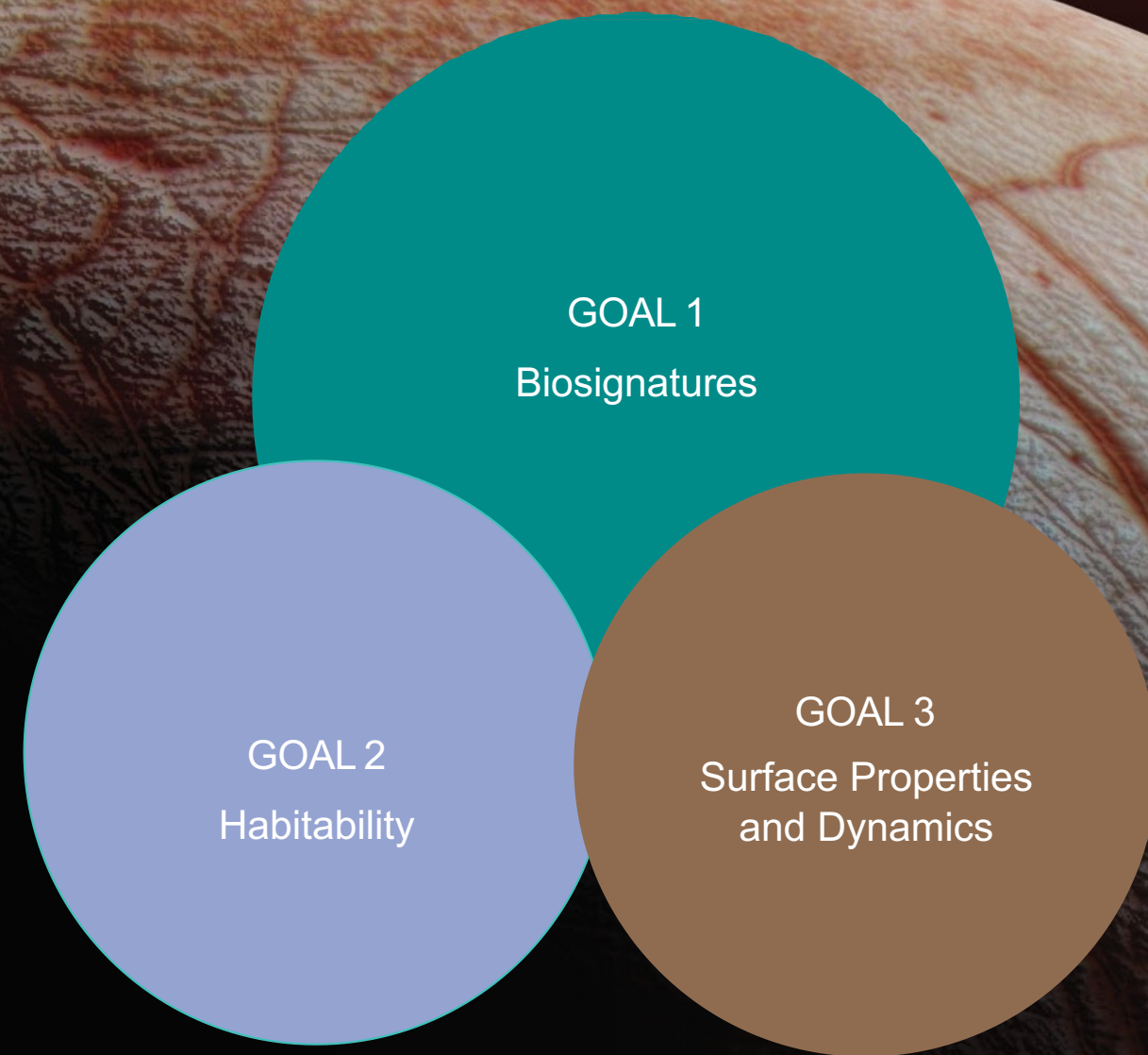
# Europa Lander Concept



Pre-Decisional Information -- For Planning and Discussion Purposes Only



# Europa Lander Concept: Science Goals



1. Search for evidence of life on Europa
2. Assess the habitability of Europa via in situ techniques
3. Characterize the surface and subsurface to enable future robotic exploration

Pre-Decisional Information -- For Planning and Discussion Purposes Only